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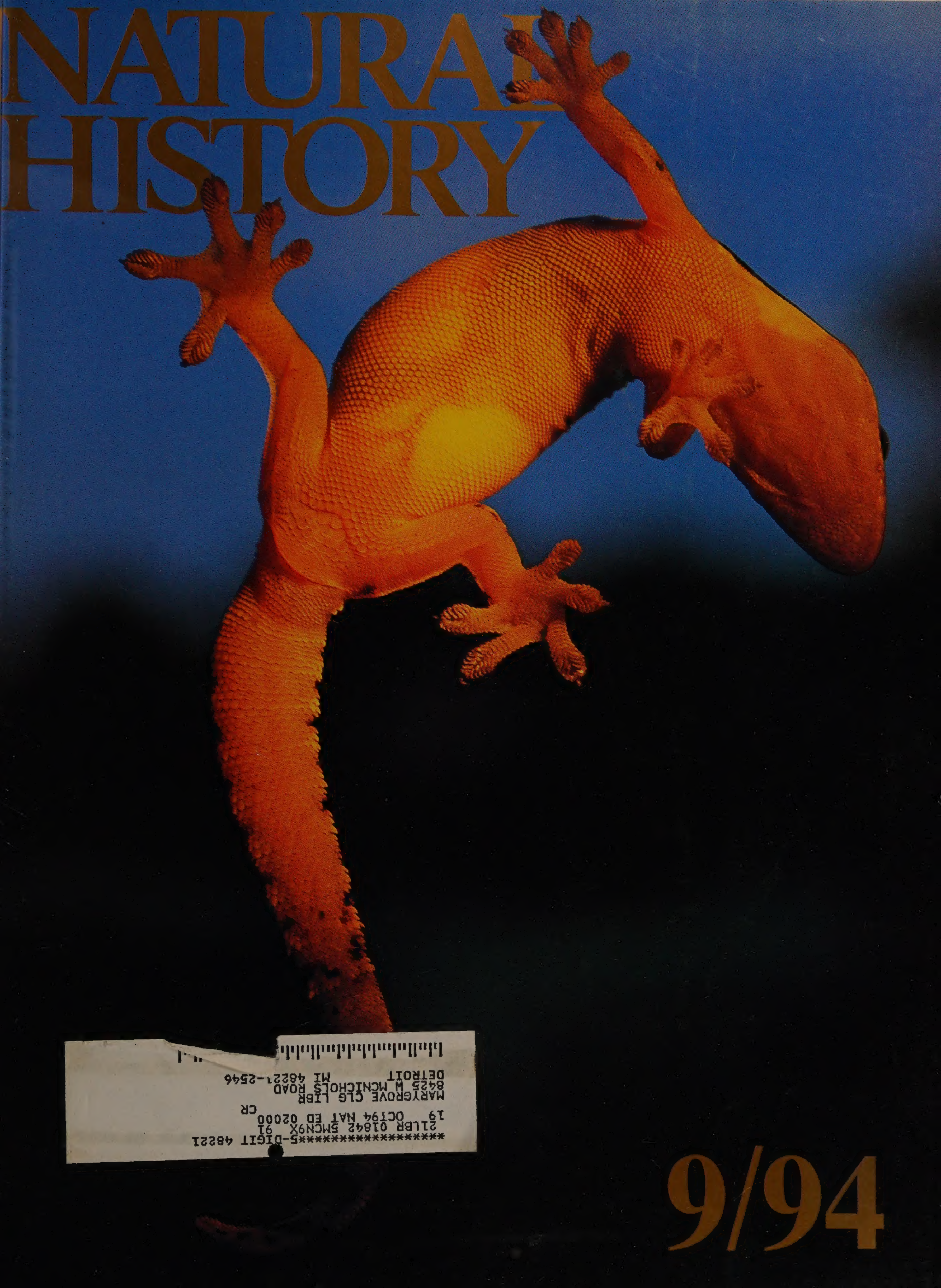

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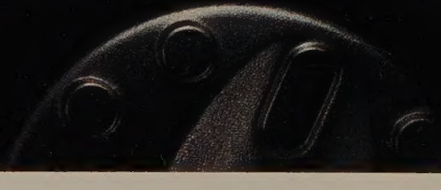

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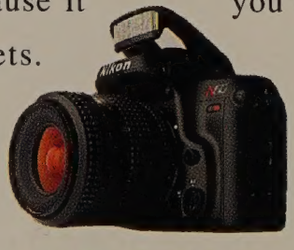

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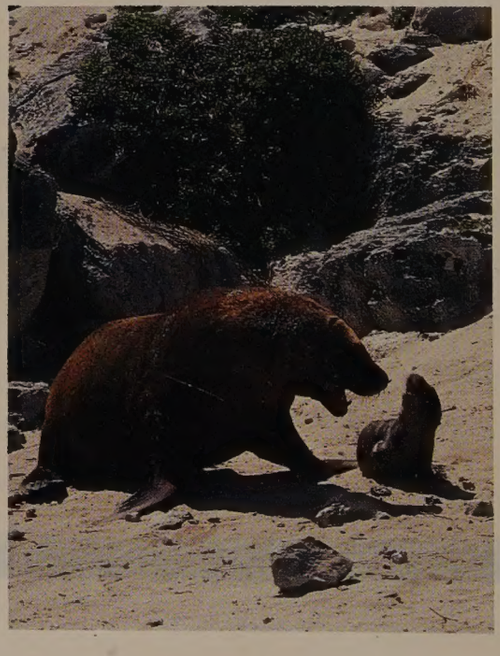
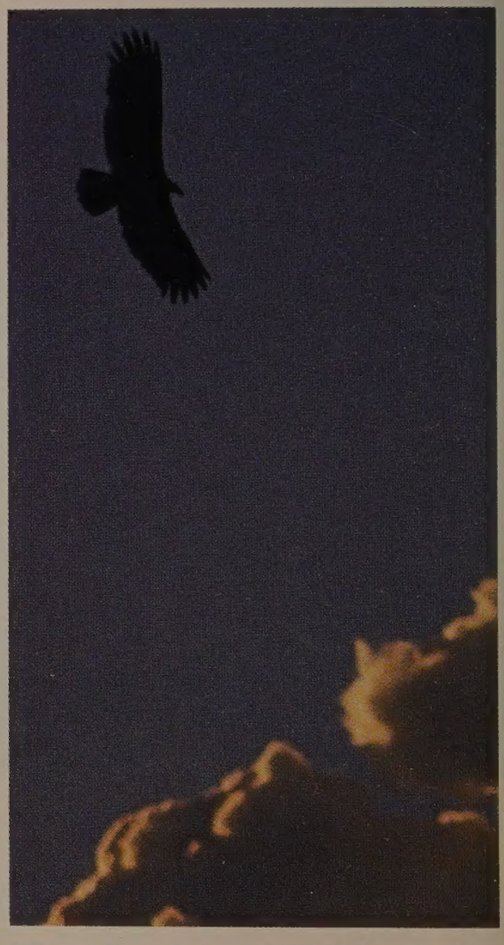
COVER: A mourning gecko, gravid with two eggs, climbs a glass pane. The lizard, once common in urban environments of Hawaii, is being driven out by a new arrival. Story on page 52. *Photograph by Mike Severns.*





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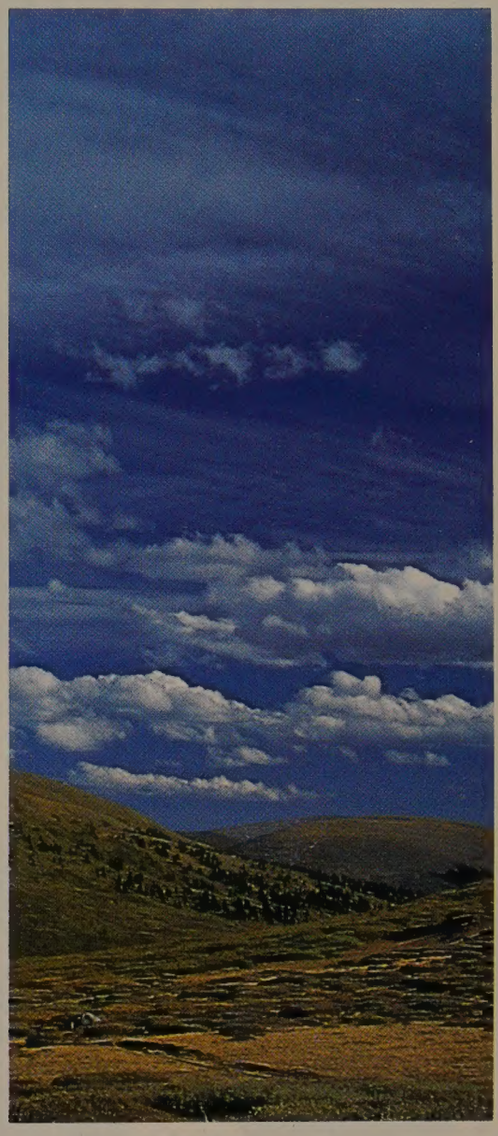
Vol. 103, No. 9, September 1994

venture, and prowess can be enhanced by rituals and magical substances. An indispensable ingredient is a large, green tree frog.



Zebras and the Anna Karenina Principle

What can Tolstoy teach us about our failure to domesticate certain animals?

by Jared Diamond

"Happy families are all alike; every unhappy family is unhappy in its own way." What did Tolstoy mean by that arresting first sentence of his great novel *Anna Karenina*?

I suppose he meant that to be happy a marriage must succeed in many different respects, and that failure in any one of those essential elements can spoil marital happiness. Sexual attraction does not assure agreement about money, while neither sexual attraction nor agreement about money assures likemindedness about child discipline, in-laws, religion, and other touchy issues. Happy marriages are all alike because the couples have achieved a good match in those and other respects. Unhappy marriages are different from one another because there are many possible causes of marital failure.

This Anna Karenina principle can be extended to understanding much about life besides marriage. We tend to seek easy, single-factor explanations for success, but for most important things, success requires avoiding many possible causes of failure. The Anna Karenina principle is on my mind now because it illuminates a question about animal domestication that has enormous significance for human history. Why have so many seemingly suitable, big, wild mammal species, such as zebras and peccaries, never been domesticated, and why were the successful domesticates almost exclusively Eurasian?

Geographic differences among the continents affected the domestication of plants, which, in turn, affected the eventual collisions between peoples (*see* "Spacious Skies and Tilted Axes," May 1994). The outcome of those collisions was that Eurasian peoples subjugated Native Australians, Native Americans, and sub-Saharan Africans, rather than vice versa. Yet at least as significant for human history were geographic factors affecting big domestic mammals. The most spectacular example was the military role of Eurasia's horses in the New World. Horses enabled Cortés and Pizarro, leading only small bands of adventurers, to overthrow the Aztec and Inca empires, respectively. Of equal importance, domestic animals were the ultimate sources of the germs that evolved into Eurasian human diseases such as smallpox and flu. Those diseases decimated the Aztecs, Incas, and many other non-Eurasian peoples lacking prior exposure.

Even in peacetime, big, domestic mammals bring enormous advantages to human societies possessing them—as sources of meat, milk, fertilizer, wool, and hides. Until the Industrial Revolution, they were the chief agents of land transport and power. Domestic animals led to denser human populations and made possible the food surpluses and transport required to support the non-food-producing specialists of stratified societies, such as full-time craftspeople, scribes, kings, and soldiers. Domestic animals, along with cultivated plants, ultimately explain why literacy, empires, and steel weapons developed earlier in Eurasia than in other continents. None of those three tools of conquest arose in aboriginal Australia, steel weapons were absent from pre-Columbian America, and writing did not develop independently in sub-Saharan Africa.

All those consequences for human history spring from the domestication of surprisingly few species of big, terrestrial, herbivorous mammals. If one defines "big" as "weighing more than 100 pounds," then only fourteen such species were domesticated before the twentieth century. Nine of those Ancient Fourteen—the Arabian camel, Bactrian camel, llama/alpaca (distinct breeds of the same ancestral species), donkey, reindeer, water buffalo, yak, banteng, and gaur—were important only in very limited areas of the globe. Five others spread worldwide. Those Big Five of mammal domestication are the cow, sheep, goat, pig, and horse.

At this point I hear shouts of reader protest: you forgot elephants! What about the African war elephants with which Hannibal's armies crossed the Alps, and what about the Asian elephants still used as work animals in Southeast Asia today? No, I didn't forget them, and that brings me to an important distinction. Elephants have been tamed, but never domesticated. A domesticated animal is defined as an animal selectively bred in captivity, and thereby modified from its wild ancestors, for use by humans who control the animal's breeding and food supply. To appreciate the resultant modifications, just compare such dog breeds as Pekingese, dachshund, or Great Dane with an ancestral wolf. All other domestic animals as

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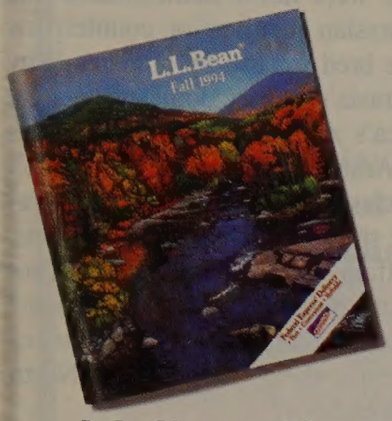
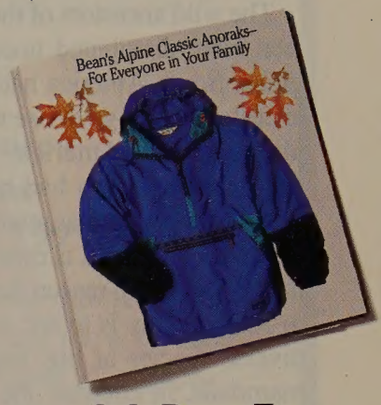


L.L.Change of Season

L.L.Places to Go

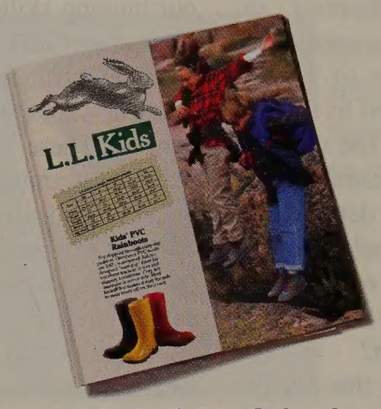
L.L.On the Road



L.L.Down East

L.L.Outdoors

L.L.Indoors



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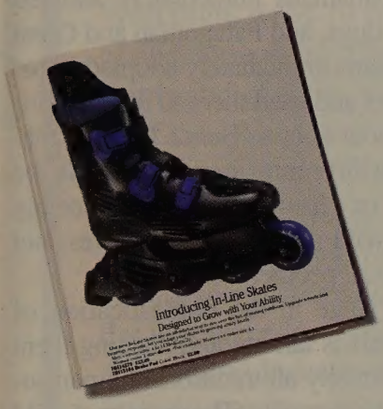

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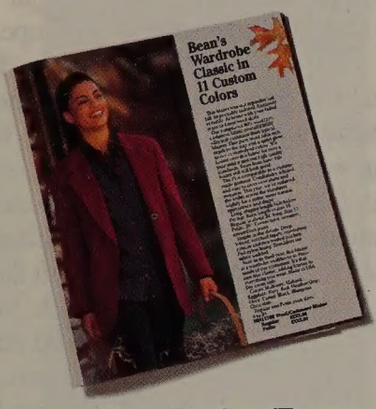

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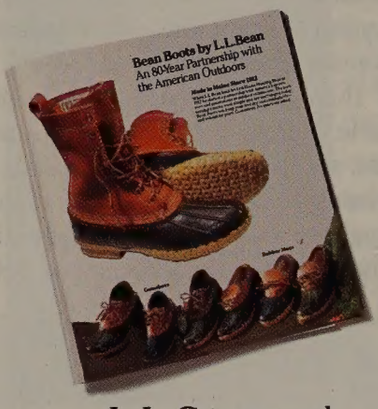

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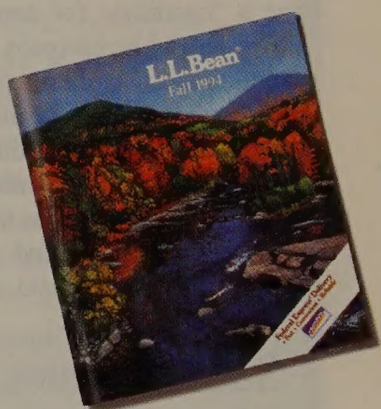

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well have been bred to differ from their wild ancestors—whether in size, color, wool, or milk output. In contrast, Hannibal's elephants were, and Asian work elephants are, wild elephants that were captured and tamed, not bred in captivity.

The wild ancestors of the Ancient Fourteen were distributed unequally over the globe. South America had only one such ancestor, which gave rise to the llama and alpaca. North America, Australia, and sub-Saharan Africa had none at all. The lack of domestic mammals indigenous to sub-Saharan Africa is especially astonishing, since a main reason that tourists travel to Africa today is to see its abundant and diverse species of big, herbivorous, wild mammals. In contrast, the wild ancestors of thirteen of the Ancient Fourteen (including all of the Big Five) were confined to Eurasia. (For the purposes of this discussion, in several cases "Eurasia" includes North Africa, which biogeographically and in many aspects of human culture is more closely related to Eurasia than to sub-Saharan Africa.) The very unequal distribution of wild ancestral species was an important factor in determining that Eurasians, rather than peoples of other continents, were the ones to end up with guns, germs, and steel. How can we explain that unequal distribution?

Part of the reason is simply that Eurasia has the largest number of big, terrestrial, wild mammal species, whether or not ancestral to a domesticated species. Let's define a "candidate for domestication" as any terrestrial herbivorous or omnivorous mammal species (one not predominantly a carnivore) weighing more than 100 pounds. As shown in the table below, Eurasia has the most candidates, seventy-two species, just as it has the most species in many other plant and animal groups. That's because Eurasia is the world's largest land mass. It is also very diverse ecologically, with habitats ranging from vast tropical rain forests to equally extensive tundras and deserts. Sub-Saharan Africa has fewer candidates, fifty-one species, just as it has fewer species in most other plant and animal groups, simply because it is smaller and ecologically less diverse than Eurasia.

The Americas may formerly have had as many candidates as Africa, but most American big mammal species became extinct about 11,000 years ago, when ancestral Indians first colonized the Americas. Among those now-extinct candidates were species, including North American horses and camels, that would probably have been domesticated had they survived. Unlike African and Eurasian mammals, which coevolved with humans and learned to fear us as we slowly developed our hunting skills over millions of years, most American big mammals suddenly encountered humans at a time when our hunting skills were already highly advanced. These mammals were probably fearless, as animals of remote islands colonized only recently by humans still are today. They would have been easy prey, quickly exterminated by the first Americans.

Australia, the smallest and most isolated continent, now has only one candidate, the red kangaroo. Australia once had other big mammals (giant kangaroos and rhinolike marsupials), but as in the Americas—and probably for the same reasons—they became extinct when the first humans arrived.

Although Eurasia was the continent with the most candidate species of wild mammals to start out with, that is not the whole explanation for the continent's edge in animal domestication. The *percentage* of candidates actually domesticated is highest in Eurasia (18 percent), and is especially low in sub-Saharan Africa (0 percent: no species domesticated out of fifty-one candidates!). Surprisingly, many species of African and American mammals that were never domesticated had close Eurasian relatives or counterparts that were bred for use by humans. Why were Eurasia's horses domesticated but not Africa's zebras? Why Eurasia's pigs but not American peccaries or Africa's three species of true wild pigs? Why Eurasia's five species of wild cattle (aurochs, water buffalo, yak, gaur, banteng) but not the African buffalo or American bison? Why the Asian mouflon sheep (ancestor of our domestic sheep) but not the North American bighorn?

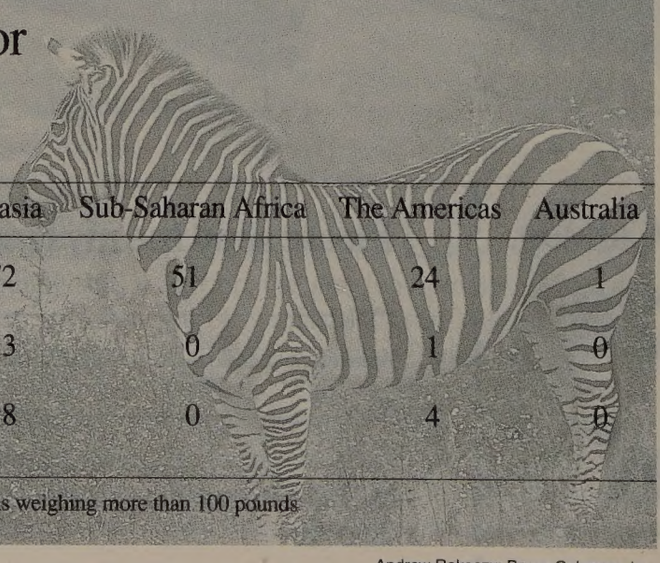
Cultural anthropologists might wonder whether there were continent-wide differences among people themselves that somehow made Eurasians especially receptive to domestic mammals. Perhaps, for instance, Africans found it superfluous to tend domestic stock because of Africa's abundance of wild game on the hoof. That explanation is refuted by Africans' ready adoption of Eurasia's Big Five mammals when they were finally introduced to sub-Saharan Africa. African peoples who acquired those Eurasian mammals—notably the Bantu farmers, the Khoi herders of southern Africa, and people of medieval west African kingdoms—thereby gained a huge advantage over other African peoples and displaced them. Similarly, aboriginal Tasmanians immediately adopted European dogs, and Patagonian and Great Plains Indians immediately adopted European horses and used them to terrorize Indians without horses. Hence the explanation for the little or no domestication in the Americas or Africa lies with the locally available wild mammals themselves, not with the local people.

A first stage in the domestication of wild animals is taming and keeping them as pets. Virtually all traditional human societies have kept pets. The variety of wild animals thus tamed is far greater than the variety eventually domesticated and includes some species that we would scarcely have imagined as pets: young grizzly bears, kept by the Ainu people of Japan; kangaroos and cassowaries in the New Guinea villages where I work; ospreys in the Solomon Islands; and hyenas, cheetahs, giraffes, and gazelles kept by the ancient Egyptians. Why did so few species that became pets emerge as domestic animals? More than a century ago, Francis Galton offered a succinct answer: "It

Success Rates for Mammal Domestication

	Eurasia	Sub-Saharan Africa	The Americas	Australia
Candidates*	72	51	24	1
Domesticated species	13	0	1	0
Percentage of candidates domesticated	18	0	4	0

*terrestrial, noncarnivorous mammals weighing more than 100 pounds



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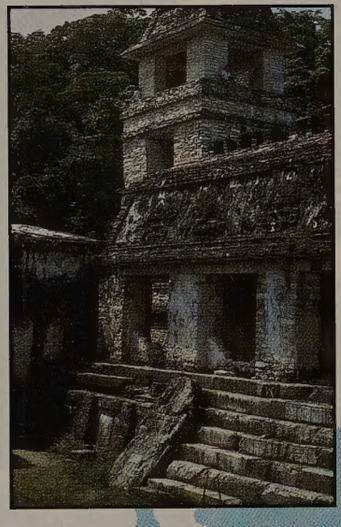

Beginning over 3,000 years ago, ancient civilizations in Mexico built magnificent cities and ceremonial centers of stone using their advanced knowledge of mathematics and astronomy. The architecture and elaborately-carved stone figures left by the Olmec, Maya, Teotihuacan, Toltec and Aztec reveal prosperous and powerful civilizations. This itinerary focuses on recent discoveries that have shed new light on the origins and interrelationships of these fascinating cultures.

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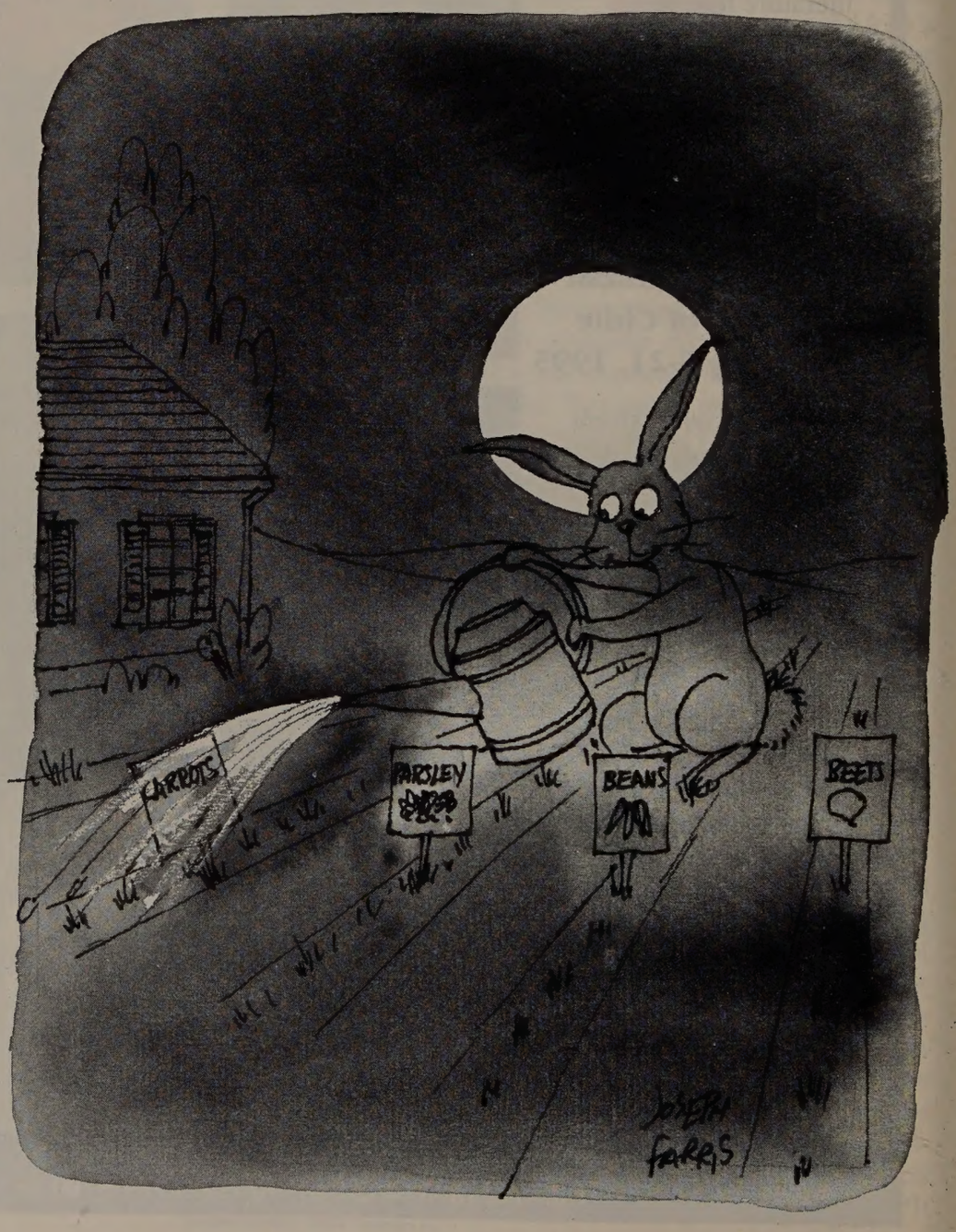
would appear that every wild animal has had its chance of being domesticated, that those few which fulfilled…[certain] conditions were domesticated long ago, but that the large remainder, who failed sometimes in only one small particular, are destined to perpetual wildness."

Three facts confirm Galton's view that early herding peoples quickly domesticated all big mammal species suitable for that fate. First, all big mammals whose initial domestication can be dated by archeological evidence were domesticated between about 8000 and 2500 B.C. The era of domestication began with the sheep, goat, and pig and ended with the Arabian and Bactrian camels and the water buffalo. Since 2500 B.C. there have been no significant additions.

Second, several of those ancient domesticates, including the pig and cow, were independently domesticated in several different parts of Eurasia. This reemphasizes that they really were the most suitable species and repeatedly attracted the domestication efforts of diverse peoples. Finally, not even modern geneticists, exercising far more draconian control over animal breeding than did ancient peoples, have been able to add to the Ancient Fourteen. Recent, well-organized efforts to domesticate the moose, elk, eland, and American bison have achieved only limited success, while efforts with zebras had to be abandoned.

In all, of the world's 148 big, wild, terrestrial, herbivorous mammals—the candidates for domestication—only fourteen passed the test. Why did the other 134 species fail? To which conditions was Francis Galton referring when he spoke of them as "destined to perpetual wildness"?



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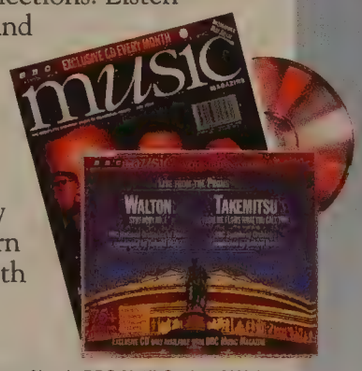

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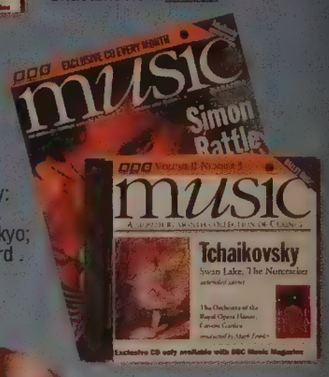

CD: Tchaikovsky: Nutcracker & Swan Lake extended suites. The Orch. of the Royal Opera House, Covent Garden (Mark Ermler). Magazine: Tchaikovsky: his mysterious death 100 years ago, Simon Rattle, Music in Tokyo; featured composer: William Byrd . C1193

CD: Schubert: Symphony No. 9 in C (Great C major). BBC Scottish Symphony Orch. (Takuo Yuasa). Magazine: Exclusive interview with Yehudi Menuhin, Soprano Anne Evans, Victor Borge: still laughing at 85; featured composer: Edward Elgar. C0194

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In accordance with the Anna Karenina principle, a candidate wild species must possess many different characteristics to be domesticated. Lack of any one requirement dooms efforts at domestication, just as it dooms efforts at building a happy marriage. Playing marriage counselor to the zebra–human partnership and other ill-sorted pairs, we can recognize at least six reasons for failed domestication:

Diet: Every time that an animal eats a plant or another animal, the conversion of food biomass into the consumer's biomass involves an efficiency of much less than 100 percent: typically about 10 percent. That is, it takes about 10,000 pounds of corn to produce a 1,000-pound cow. If you want 1,000 pounds of carnivore, you have to feed it 10,000 pounds of herbivore grown on 100,000 pounds of corn. As a result of this fundamental inefficiency, no mammalian carnivore has ever been domesticated as a food animal. (No, it's not because its meat would be tough or tasteless: we eat carnivorous wild fish all the time, and I can personally attest to the delicious flavor of lion-burger.) The nearest thing to an exception is the dog, which was raised for food in Polynesia and Aztec Mexico and still is in parts of Asia. However, dogs are not strict carnivores but omnivores, as you can confirm by reading the list of ingredients on any bag of dog food. Dogs reared for food are efficiently fattened on vegetables and garbage. Even among herbivores and omnivores, some species, such as koalas, are too finicky in their plant preferences to have been domesticated.

Growth rate: To be worth keeping, domesticates must also grow quickly. That eliminates gorillas and elephants, even though they are vegetarians with admirably nonfinicky food preferences and represent a lot of meat. What would-be gorilla rancher or elephant rancher would wait ten to fifteen years for his herd to reach adult size? Modern Asians who want work elephants find it much cheaper to capture them from the wild and tame them.

Problems of captive breeding: We humans don't like to have sex under the watchful eyes of others; some potentially valuable animal species don't like to either. That's what derailed efforts to domesticate cheetahs, the swiftest of all land animals, despite our strong motivation to do so for thousands of years. Tame cheetahs were prized by ancient Egyptians, ancient Assyrians, and modern Indians as hunting animals infinitely superior to dogs. One Mogul emperor of India kept a stable of a thousand cheetahs. But despite the large investments that many wealthy princes made, all their cheetahs were caught in the wild and tamed. The princes' efforts to breed cheetahs in captivity failed, and even biologists in modern zoos did not achieve their first successful cheetah birth until 1960. One reason is that in the wild a group of cheetah brothers chase a female for several days, and that rough courtship over large distances seems to be required to get the female to ovulate or to become sexually receptive. Captive cheetahs usually refuse to carry out that elaborate courtship ritual. A similar problem has derailed efforts to breed the vicuña, an Andean wild camel highly prized for its fine, light wool.

Nasty disposition: Some animal species are more vicious than others, and species that regularly try to kill their human caretakers do not make good livestock. That's what prevented the Ainus from domesticating grizzly bears, which they traditionally captured as cubs but wisely slaughtered within a year. Africa's buffaloes, hippos, and rhinos all represent a ton or more of meat on the hoof and would have been ideal livestock—had they not been the most dangerous and unpredictable of African mammals.

Few people would be surprised at the disqualification of those notoriously vicious candidates. But there are other disqualified candidates whose difficult and dangerous dispositions are not so well known. The eight species of wild equids, for instance, vary greatly in disposition. Two of them, the horse and the North African ass (ancestor of the donkey), were successfully domesticated. The closely related onager, or Asiatic ass, seems to have been used for cross-breeding and incipient domestication experiments in ancient times, but its evil temper caused those attempts to be abandoned. Africa's zebras proved even worse. They were tried out as draft animals in the nineteenth century in what is now South Africa, and eccentric Lord Walter Rothschild hitched zebras to his carriage on the streets of London. But zebras become impossibly dangerous as they grow older. They have the unpleasant habit of biting a person and not letting go until the victim is dead. As killers of zookeepers, zebras rank not far behind lions and tigers. As a result, it has been impossible to saddle or ride zebras, and South African enthusiasm for their domestication waned.

Tendency to panic: Big mammalian

herbivore species react to danger from predators or humans in different ways. Some species are nervous, fast, and programmed for instant flight when they perceive a threat. Other species are slower, less nervous, seek protection in herds, stand their ground when threatened, and don't run until necessary. Most species of deer and antelopes are of the former type, while sheep and goats are of the latter.

Naturally, the nervous species are difficult to keep in captivity. If penned, they are likely to panic, and will either die of shock or batter themselves to death against the fence in their attempts to escape. That's true, for example, of gazelles, which for thousands of years were by far the most frequently hunted game species of the Fertile Crescent, cradle of Western civilization. There is no mammal that the first settled people of the Fertile Crescent had more opportunity to domesticate than the gazelle. But no gazelle species has ever been domesticated. Just imagine trying to herd an animal that bolts and blindly bashes itself against walls, that can leap as much as thirty feet forward, and run at a speed of fifty miles per hour!

Social structure: Almost all species of domesticated large mammals prove to be ones whose wild ancestors share three social characteristics: they live in herds; they maintain a well-developed dominance hierarchy among herd members; and the herds occupy overlapping home ranges rather than mutually exclusive territories. For example, herds of wild horses consist of one stallion and up to a half dozen mares and their foals. Mare A dominates mares B, C, D, E; mare B is submissive to A but dominates C, D, and E; and so on. When the herd is on the move, its members maintain a stereotyped order: in the rear, the stallion; in the front, the top-ranking female, followed by her foals in order of age, with the youngest first; and behind her, the other mares in order of rank, each followed by her foals in order of age. In that way, many adults can coexist in the herd without constant fighting.

Such social structure is ideal for domestication, because humans in effect take over the hierarchy. Domestic horses of a pack line follow the human leader instead of the top-ranking female. Herds or packs of sheep, goats, cows, and ancestral dogs (wolves) have a similar hierarchy. As young animals grow up in such a herd, they imprint on the animals that they regularly see nearby. In the wild, those are members of their own species, but captive young herd animals also see humans nearby and become imprinted on them. Because herd members tolerate one another in the wild, they can also be bunched up and penned.

Solitary territorial animals cannot be herded. They do not tolerate one another, they do not become imprinted on humans, and they are not instinctively submissive. Who ever saw a line of wild cats following a human, or allowing themselves to be herded by one? Every cat lover knows that cats are not submissive to humans in the way that dogs instinctively are. Cats and ferrets are the only solitary, territorial mammal species that were domesticated, because our motive for domesticating them was not to herd them in large groups raised for food, but to keep them as hunters or pets.

While most solitary territorial species have not been domesticated, it is not conversely the case that most herd species can be domesticated. Most can't, for one of several additional reasons.

First, herds of many species do not have overlapping home ranges but instead maintain exclusive territories against other herds. It is no more possible to pen two such herds together than it is to pen two males of a solitary species. For instance, vicuñas live in herds of up to ten animals, consisting of one male, his harem, and their young. But each herd has an exclusive feeding territory and also an exclusive sleeping territory. This behavior, as well as finicky mating habits, prevented domestication of vicuñas.

Second, many species live in herds for only part of the year, becoming combative and territorial during the breeding season. Most deer and antelope species follow this pattern, a crucial factor that disqualified all of Africa's social antelope species.

Finally, the social systems of many herd species, again including most deer and antelope, are not well-defined dominance hierarchies, so the animals are not instinctively prepared to become imprinted on a leader (and hence to become misimprinted on humans). Although many deer and antelope species have been tamed (think of all those true Bambi stories), one never sees tame deer and antelopes driven in herds like sheep. That problem also derailed domestication of North American bighorn sheep, which belong to the same genus as Asiatic mouflons, ancestor of our domestic sheep. Bighorns are similar to mouflons with one crucial exception: they lack the mouflon's stereotyped submissiveness to dominant individuals.

Bighorns illustrate the paradox that close relatives of domesticated species often are not themselves domesticable. Other examples are the zebra and onager (closely related to the horse and donkey), the African buffalo (cow and water buffalo), and the vicuña (llama/alpaca). A final example can be found in Perissodactyla, the order of odd-toed hoofed mammals that includes horses, rhinos, and tapirs. The two perissodactyls that have been domesticated—the horse and the North African ass—belong to the same genus. No species of tapir or rhinoceros has ever been domesticated, although domestic tapirs would have been great assets to Native Americans and domestic rhinos would have been great assets to Africans. Just picture what a charge of African cavalry mounted on rhinos would have done to the ranks of would-be conquering European soldiers! Alas for Native Americans and Africans, all tapir species are solitary, and rhinos are territorial (at least males are in the breeding season) and dangerously nasty, disqualifying them as domesticates.

In short, Eurasians' advantages—guns, germs, and steel—were in large part the luck of the draw: Europeans happened to inherit many more species of domesticable, large, wild, mammalian herbivores than did people of the other continents. Small and isolated, Australia had few candidates to begin with, and all but one of them became extinct (were exterminated?) when the first human hunters reached Australia. The Americas initially had many candidates, but most of them also disappeared when human hunters arrived. Only Eurasia and Africa escaped massive late-Pleistocene extinctions of big mammals because mammals of those continents had coevolved with humans for a long time. Unlike their Australian and American counterparts, they weren't suddenly exposed to humans late in our evolutionary history, when our hunting skills were already highly developed.

On all continents, most candidates for domestication were eliminated by the Anna Karenina principle. Humans and most animals make an unhappy marriage, for one or more of the many possible reasons cited: animal diet, growth rate, mating habits, disposition, tendency to panic, and social organization. Tolstoy would have approved of the insight offered by an earlier author, Saint Matthew: "Many are called, but few are chosen."

Jared Diamond is a physiologist and evolutionary biologist at UCLA Medical School.

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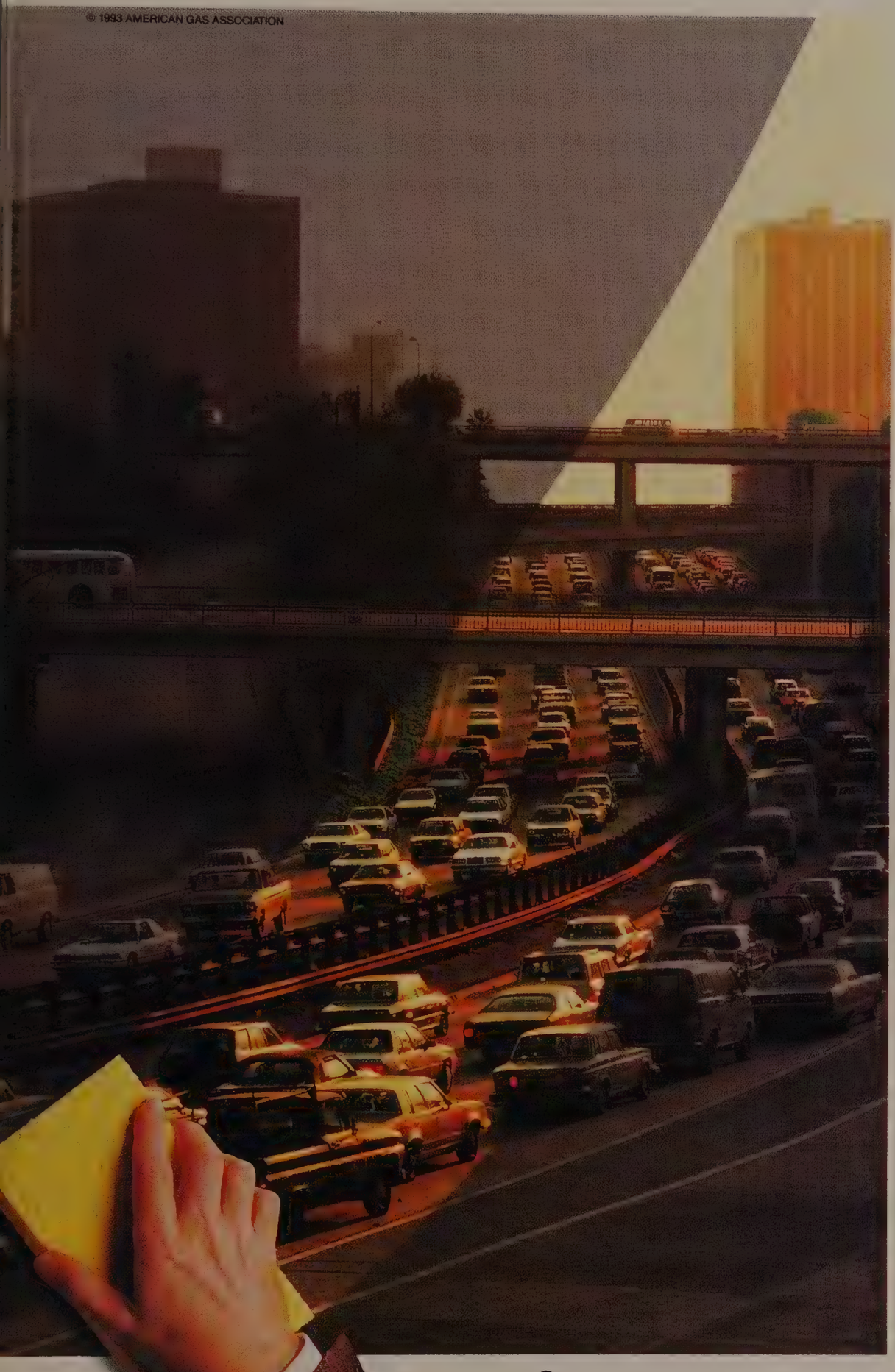

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Lucy on the Earth in Stasis

Ethiopian hominids were in no hurry to become human—and an evolutionist is not surprised

by Stephen Jay Gould

Queen Victoria, just a bit behind the times as usual, took her first journey by railroad in 1842—from Windsor to London (by 1840, the United States already had 2,816 miles of track in operation, while England boasted 1,331 miles). Beyond this royal symbol, 1842 was a good year for change in general. Darwin composed his first sketch of the theory of natural selection (followed, in 1844, by an expanded draft and finally, in 1859, by a published version, *The Origin of Species*). And in *Locksley Hall,* Alfred, Lord Tennyson, wrote the most famous of all Victorian lines about the inevitability of change: "Let the great world spin forever down the ringing grooves of change."

I unite Tennyson's line with Victoria and rail transport for several reasons, most literally because Tennyson himself later wrote that his striking, though peculiar, metaphor for change (both visual and aural) arose from a misperception during his own first journey by rail: "When I went by the first train from Liverpool to Manchester (1830), I thought that the wheels ran in a groove. It was a black night and there was such a vast crowd round the train at the station that we could not see the wheels. Then I made this line."

We are beset by dualities, perhaps because nature favors pairings, but more, I suspect, because our mind works as a dichotomizing machine: night and day, sun and moon, male and female, life and death (*the* question, as Hamlet told us). Among the organizing dualities of our consciousness, change and constancy stands out as perhaps the deepest and most pervasive. Heraclitus said that we can't step twice into the same river, while his contemporary Pythagoras tried to extract invariance from the world's overt complexity by discovering simple regularities in number and geometry—a scholar's dream still pursued, as by Bertrand Russell in our day, when he included among the three passions of his life, "I have tried to apprehend the Pythagorean power by which number holds sway above the flux."

These deep dualities cannot be analyzed in terms of truth and falsity, for the two sides are both and neither. In our struggles to comprehend this immensely puzzling and amazingly intricate universe, both themes of change and themes of constancy yield crucial insights for different questions and different scales. Since the two sides of this duality are equally true and useful, the favoring of one or the other at various, fluctuating times in the history of science becomes our best illustration of social impact upon a process that mythology regards as free of personal preference and driven exclusively by observation—for no organizing construct of the mind can be more socially and politically influenced than our transient preference for either change or stability as the essential nature of the universe.

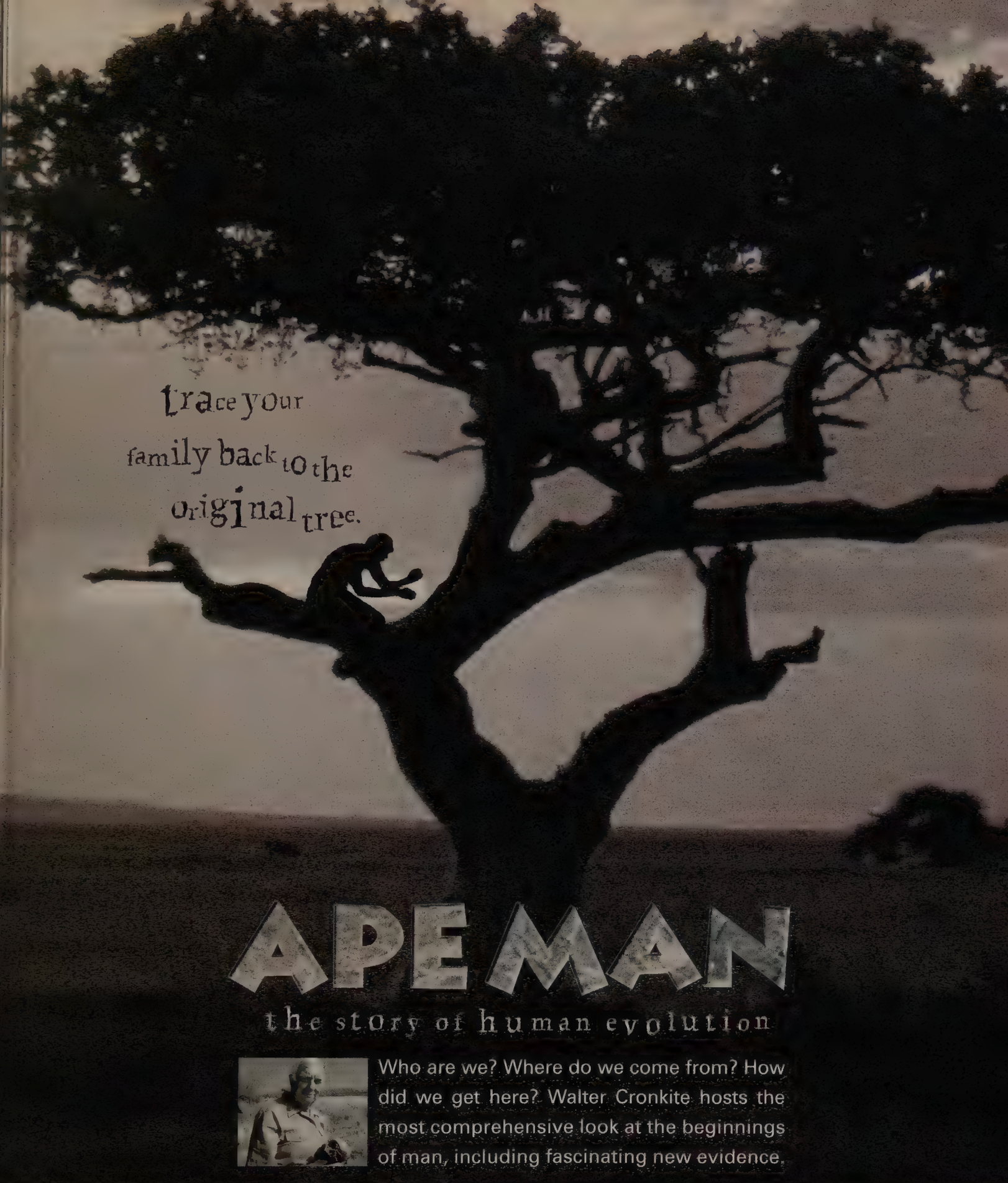
Many periods of Western history have favored stability if only as a supposed natural buttress to a ruling political hierarchy of monarchs and nobles or popes and bishops. But a fundamental tenet of Western life, at least since the late eighteenth century, has proclaimed change as natural and constant. Social conservatives may rail and moan, visionaries and romantics may dance and sing, but the ringing grooves have dominated our view of the world for the past two centuries at least. Belief in change as nature's essential way blossomed in the eighteenth-century age of revolutions, with America and France leading a sometimes ambiguous way, flourished with the subsequent wave of romanticism in the arts, and reached an apogee (for Tennyson chose his metaphor wisely) with the even more ambiguous Victorian triumph of industrial and colonial expansion.

Evolution is a fact of nature—one that could probably not have been perceived, and certainly not widely promulgated, before preference for change in this cardinal duality swept the Western world. But evolution also enjoyed a much easier path to acceptance in Darwin's century because its central theme of change meshed so well with prevailing social context. Biological evolution, with its unbeatable combination of empirical truth and social fit, therefore became the quintessential theory of change within Western science.

Obviously, I do not write this essay to challenge evolutionary change because one side of its popularity has a social root. But I do wish to stress the importance of acknowledging social influence as the best possible antidote to overconfidence about our perception of truth and the best spur to healthy skepticism and self-examination. Much of what we regard as empirically proven, or logically necessary, may only be a contingent reflection of transient social preferences. And if notions of change as nature's essence rank among the strongest of these social preferences, then we need to be especially skeptical when we weigh our assumptions about the character of change.

Social preference extends beyond a simple belief in change as essential to a set of assumptions about the nature of change. In particular, we usually view change as intrinsic and continuous, not rare and episodic. That is, we wish to conceptualize change as its own form of constancy, to define systems by their changes, and to view continuous alteration as a normal state—particularly of systems undergoing biological evolution.

But other theories of change are just as consistent with the general view of a universe driven by alteration. For example, stability might reign most of the time, and change might be a rare event, usually of



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substantial magnitude and occurring only when stresses impact a system beyond its capacity to absorb without substantial modification. In this alternative view, stability is the norm for most systems most of the time—and change, while driving the universe in the fullness of vast scales and long times, is absent at almost any given moment.

This conflict between change as continuous and steady versus rapid and episodic underlies many debates in the history of science—the great late-eighteenth through early-nineteenth-century struggle (when general theories of change had just become dominant and were therefore flexing muscles and dividing turf) between uniformitarianism and catastrophism for the physical history of the earth and the biological alteration of faunas, or (to cite a contemporary skirmish of much smaller scale) the debate between punctuated equilibrium and gradualism for the process of speciation in biological lineages.

I shall not hide my preferences and biases. I helped to devise the theory of punctuated equilibrium with Niles Eldredge in 1972, and we rejoiced last year in the majority of our child (now able to drink, in addition to driving and voting—but not, we pray, at the same time). I have cheered from the sidelines (and occasionally given a boost in these essays) as catastrophic theories of mass extinction make their comeback in the virtual proof now available for extraterrestrial impact as the trigger of the Cretaceous–Tertiary dying.

I am not a foe of gradual change; I believe that this style of alteration often prevails. But I do think that punctuational change writes nature's primary signature—and I am convinced that our difficulty in conceptualizing this style of alteration arises from social and psychological bias rather than from any shyness of nature in printing its John Hancock (so conspicuously that the king might read it without his spectacles—although we poor ordinary mortals often seem blind, however prominent the signature).

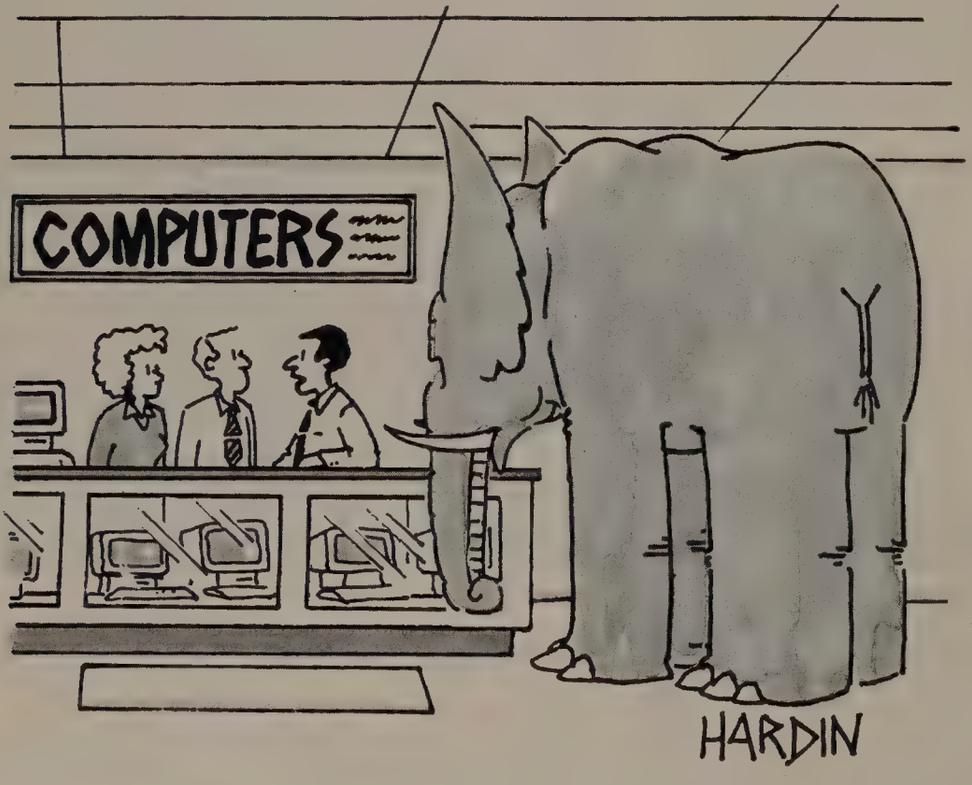
I have come to understand, in a different and personal way, that an equation of evolution with a belief in continuous change as nature's norm sets the most pervasive misconception of life's history in the general culture of intelligent and well-educated lay audiences. At this point in my mid-career as a writer and lecturer, I have given so many hundreds of talks, and received so many thousands of letters, that I have a good sense of recurring themes and their relative frequencies. Some questions arise rarely; a few are unique and wonderfully idiosyncratic or challenging. But other questions occur with such predictable regularity that they inspire such clichéd comments as, "If only I had a dollar for each time I've heard that one, I could retire to a life of indolent luxury."

I do not regard these inevitable questions as stupid in any sense. Quite the contrary: I hear them every time I speak because they are good questions coming from the heart of human concern, interest, and puzzlement. But such questions are often based on deep misconceptions about the nature of evolution. In fact, people get stuck on these questions precisely because they grasp (however dimly) an inconsistency between the empirical world and a formulation that seems exclusive or inevitable according to their understanding of evolutionary theory. The solution does not lie in revising facts, but in forcing a conceptual reformulation that switches the facts from anomaly to expectation.

My two most common questions (really less and more sophisticated versions of the same concern) are rooted in the fallacy of assuming that evolution means continuous change, and that stability must therefore count as the most puzzling of anomalies. The first, less sophisticated version simply asks: "Where is human evolution going in the future?"

Questions are not neutral; they presuppose a list of assumptions that may be quite long and complex. This query begins with a belief that evolution is always going somewhere and that we would especially like to know where such a universal process will lead parochial little us. I feel that I can only respond with a question of my own: "Why do you think that we are or ought to be going anywhere?" I then try to explain that human bodily form has been stable for tens of thousands of years (during which everything that we call civilization has been built without substantial alteration in any physical aspect of brains or bodies that the fossil record might preserve). I then add that stability on scales of hundreds of thousands to millions of years is a norm and expectation for large, successful, geographically widespread populations. Evolution tends to be concentrated in events of branching speciation, and such events usually occur in small and isolated populations. Humans live all over the world, move vigorously from place to place, and maintain an apparently unstoppable habit of interbreeding everywhere they go—therefore we permit ourselves no opportunity for isolation and speciation (unless you want to construct a science fiction scenario about space colonies). Thus, I can only answer this most inevitable of questions by saying that we are unlikely to be going anywhere in the ordinary course of things (all bets are off with such culturally devised phenomena as genetic engineering), and that evolutionary theory predicts and expects such stability.

The more sophisticated version comes from listeners who already know the facts of long-term recent stability, regard the sit-



"He wants a system with lots of memory, but without a mouse."

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uation as strongly anomalous, have thought about it, and have devised a potential explanation (which would be quite sensible if the misconceived equation of evolution with continuous change were valid): "Does the recent stability of human bodily form arise because culture has suppressed the ruthless action of natural selection and halted the process of weeding out the unfit, thus blocking adaptive evolutionary change?"

I try to answer this version in two parts. I first identify this question as a vestigial holdover from old-style eugenics and its false assumption—the bastion of the misnamed and discredited doctrine of "social Darwinism"—that human "progress" requires a relentless struggle in the overt gladiatorial mode, with victors rising to positions of power and inferior folks either put to the wall or precipitated into the lower classes. In this view, culture stymies nature by permitting the unfit to survive (through such derailments of Darwinian order as manufacturing eyeglasses, hearing aids, and wheelchairs). "Bad" genes accumulate and evolutionary toughening grinds to a halt.

I confess that I do get cross in noting the astonishing persistence of such a badly formulated and socially pernicious argument. Genes leading to eyes that require corrective lenses are not "bad" in any absolute sense; they do increase our dependence upon culture (to supply the needed assistance), but human life is now so inextricably dependent upon culture for a thousand other reasons that I cannot imagine why we would choose to lament this additional link. As the only evolutionary consequence that I can imagine, such a cultural "softening" of natural selection may slightly boost our genetic variability as a species, but I cannot regard such an increase as anything but neutral or favorable.

But I then point out that the initial question rests upon what logicians label an "unarticulated major premise" and we ordinary folk call a "hidden assumption"—the same one that motivated this essay. If we suggest that cultural softening caused human stability, then we imply a prior (though unstated) belief that evolutionary change is a natural norm—and that any failure to note such change requires a special explanation. But if the norm for species like ours is really stability, then the anomaly vanishes, and the question resolves itself into a nonissue.

As another cultural test of the prejudicial hold imposed upon our understanding of evolution by the doctrine of continuous change as a defining norm, we might consider press reporting of discoveries that affirm substantial intervals of stasis on the human family tree. Are such findings reported as affirming an expectation or presenting a strong surprise? I have long noted that surprise always dominates, and I decided to write this essay because such a fine example has just appeared in newspapers and magazines throughout the world.

"Gosh. You really do eat like a bird."

The March 31, 1994, issue of *Nature*, Britain's leading professional journal of science, featured a strikingly apelike human fossil skull on its cover, above the heading "Son of Lucy." The technical article within, by William H. Kimbel, Donald C. Johanson, and Yoel Rak, bore the less titillating title, "The First Skull and Other New Discoveries of *Australopithecus afarensis* at Hadar, Ethiopia."

The human lineage branched off from the clade of our closest cousins, chimpanzees and gorillas, about 6 to 8 million years ago—a date inferred from genetic distances among living species, not from direct evidence of fossils. The first well-dated and clearly accepted human fossils are 3.9 million years old and come from strata in Ethiopia. All fossil humans spanning the first million years of our recorded history (3.9 to 3.0 million years ago) belong to the single species *Australopithecus afarensis*, named by D. C. Johnson, T. D. White, and Y. Coppens in 1978. (The name *Australopithecus* means "southern ape" and honors the first discoveries of later species in this genus from South Africa in the 1920s; *afarensis* refers to the Afar region of Ethiopia, where this earlier species was found.)

During the 1970s, nearly 250 fossils of this species were recovered from the main site at Hadar by a team led by Don Johanson. This trove included a 40 percent complete female skeleton now famous throughout the world by its field name, Lucy, given to honor the Beatles' famous and somewhat cryptic song about a hallucinogenic substance once popular in certain segments of society. (The coining of informal and irreverent field names is a hallowed pastime among paleontologists, although few find their way into popular speech; I will not bore you with the names of various snails I have collected.)

Nature often plays cruel jokes on us if only to keep this little evolutionary twig in its proper place. Johanson's 250 fossils constituted one of the richest finds in the history of human paleontology. Our skeleton includes about 100 bones, and many fossilize poorly. We are intrigued and informed, above all, by skulls—not only for prejudicial reasons of traditional overemphasis upon brainpower (or lack thereof in our earliest ancestors) but also for the more legitimate reasons that skulls are so complex and therefore so informative and diagnostic. With so much material, we might have expected a good skull or two. But, alas, not a single skull, or even a really good fragment, arose from this mag-

I returned home only to discover my sketch pad was blank.

Amy Cunningham recalls one of Mississippi's state parks.

Cameras with long lenses may be the most expedient way to capture waterfowl, but I've always derived more satisfaction putting simple pencil to paper, then trusting my memory when I'm at the easel. Besides, I paint strictly for pleasure, not for the purists.

That's probably a good thing, too, considering I came home blissfully empty-handed from my long weekend in Mississippi. I couldn't help it. When I looked up and saw the Great Blue Heron wading in the shallows, I froze. He was almost touchably close and I knew if I moved, he'd take flight.

In my mind's eye, I hurriedly sketched page after page in exquisite detail. I filled the pages front and back. By the time he'd flown away, I knew every feather and the glint of his obsidian eye.

I don't know how long we looked at each other in our total stillness. It was long enough for the light to change, of that I'm sure. And it was long enough for my heart to change as well, because in the eye of a heron, deep in the heart of Mississippi, I knew I'd found a state of grace.

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nificent collection. Lucy remained headless. (Johanson and his team did try to piece a skull together from numerous fragments found in distant places, but this reconstruction was too partial and conjectural to win much approval.)

Moreover, this rich material provoked as many puzzles and controversies as it provided new and clear information. In particular, the large difference in body size between two groups of bones included within these fossils sparked a lively debate between two interpretations. Do these groups represent males and females of a single species? Or might two species be hiding under the single name *Australopithecus afarensis*? Modern humans average about 11 percent difference in length of arm bones between males and females, while the two groups included in *A. afarensis* average 22 to 24 percent for the same measures. Proponents of the "two species" theory argue that this difference is too great for sexual dimorphism in a single species, but proponents of the "two sexes" theory (I will not hide my allegiance with this school) reply that many primates, including gorillas, equal or exceed this degree of sexual dimorphism, and that other species of the genus *Australopithecus* also exhibit nearly as high a degree of difference between groups accepted as sexes of a single species.

Obviously, the best way to resolve such controversies demands an exit from armchairs and the polemic factory of academic publication, and reentry into the field to search for more fossils. Johanson and colleagues have been following this excellent strategy for several years, and have been richly repaid with fifty-three new specimens from the Hadar region, including the best possible reward of an excellent skull—a large male dubbed, unsurprisingly, "son of Lucy."

I was delighted to note the theoretical emphasis that Kimbel, Johanson, and Rak chose to place upon their skull and related finds. Of all the issues raised by these important fossils, the three authors emphasized evidence for prolonged stasis within *A. afarensis* as their primary and most interesting conclusion. This evidence includes two parts: first, the further affirmation that only one species, with strong dimorphism between sexes, lived in this region (and perhaps anywhere on the human family tree) during this formative interval of nearly a million years; second, the strong evidence for morphological stability in *A. afarensis* throughout this long time. The three authors roll both conclusions into the final sentence of their abstract: "They [the new fossils] confirm the taxonomic unity of *A. afarensis* and constitute the largest body of evidence for about 0.9 million years of stasis in the earliest known hominid species."

The new finds provide evidence for prolonged stasis in *A. afarensis* by extending the geological range of this species in both directions. Heretofore, firmly identified specimens occupied the short interval between 3.18 million years old (the best date for Lucy herself) to 3.4 for the oldest material from Hadar. (At 3.5 million years old, the famous footprints at Laetoli, presumably of a male and female walking in tandem, probably represent *A. afarensis* as well, but however stunning, footprints are impressions, not bones.) The new skull, at 3.0 million years old, represents the youngest known material of *A. afarensis*. Since the bones are indistinguishable from skull pieces found earlier among the older specimens, Lucy's "son" demonstrates nearly half a million years of stasis in the first distinctive species of our distinctive evolutionary bush.

Extension to older times rests on more tenuous inference, but still represents our best tentative conclusion on limited evidence. In 1987, B. J. Asfaw described a large fragment of the diagnostic and taxo-

nomically important frontal region of the skull (including brow ridges) from substantially older rocks at the nearby site of Belohdelie. He tentatively attributed this 3.9-million-year-old skull piece to *A. afarensis,* but could not be sure because Johanson's main trove of younger material from Hadar included no well-preserved frontal bone for comparison. The Belohdelie frontal has therefore rested in limbo for several years. But the new skull of Lucy's son includes a complete frontal region—and it is indistinguishable from the 0.9-million-year-older material at Belohdelie. Admittedly, identity in the frontal region is not proof of stasis throughout the skeleton, but Belohdelie is all we have of Lucy's earliest years, and stasis does prevail for the information available.

Thus, strong evidence from much of the skeleton indicates stasis in *A. afarensis* for nearly half a million years (quite a good chunk of time already), from the oldest Hadar specimens at 3.4 million years to the skull and associated bones of Lucy's son at 3.0 million. Limited material from part of the skull also shows no change in recorded morphology right back to the earliest specimen of *A. afarensis* at 3.9 million years.

The first specimens on the hominid bush therefore persisted in stasis, as illustrated by all available positive evidence, for its entire recorded range of nearly a million years. (Some people have a false impression that claims for stasis rely on negative evidence or absence of demonstrated changes. On the contrary, stasis should be a positive conclusion based upon hard anatomical evidence of nonchange through substantial time. We must also remember that the oldest and youngest specimens are only the first and last so far found, not the full range of the species. *A. afarensis* might have lived even longer in stability—but now I am speculating with negative evidence, and I had best shut up.)

Nature had put a press embargo on the story of Lucy's son until its official publication date of March 31, and journalists do respect these fair conventions. Thus, press reports of the discovery all appeared in a single whoosh (for reporters had enjoyed ample lead times to prepare their stories) in newspapers for March 31 or April 1 (no joke)—thereby enhancing the force of a global "experiment" to test whether reported stability surprises even well-informed people because they equate evolution with continuous change.

I was delighted to note that two articles did describe Lucy's son in the light of punctuated equilibrium, therefore recognizing stasis as the prediction of this theory, rather than as a surprising anomaly, disconnected from any proposed explanation. The *Miami Herald* wrote: "Experts in human origins...said the new skull is a compelling argument for the theory that the evolution of human life on Earth proceeded in fits and starts, with long periods of stasis punctuated by sudden periods of change." Giles Whittell, writing in the *Times* (London) under a headline "Skull Find Backs Evolution Leap," stated: "The 3 million year old skull...lends weight to the view that evolution was not gradual but sporadic, involving long periods of no progress at all.... *A. afarensis* flourished unchanged for almost a million years."

But the great majority of stories professed pure surprise that our evolutionary adventure should have begun with a million years of stability. "Remarkable" surely led the pack as an adjective to modify stasis (J. N. Wilford in the *New York Times,* and R. C. Cowen in the *Christian Science Monitor,* who wrote: "What's remarkable about this 3 million year old fossil is not that it is so old but that it's so young. It is 200,000 years younger than the famous Lucy...and a million years younger than the oldest specimen. Yet it

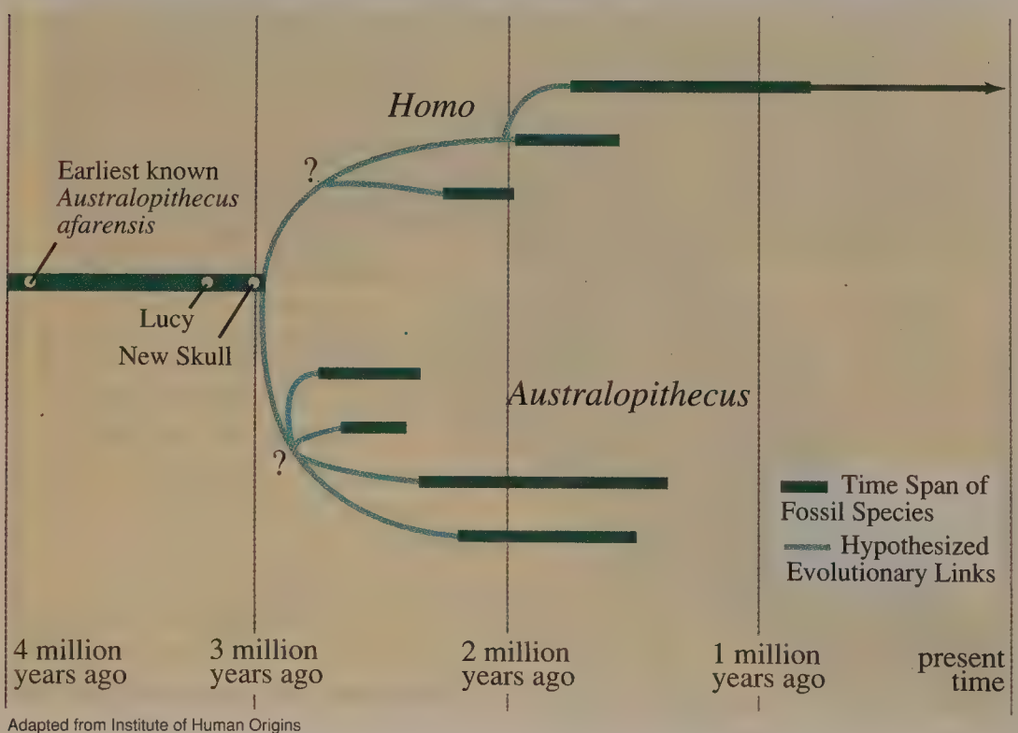
looks like those ancestors"). Among other adjectives, Tim Friend in *U.S.A. Today* favored "unexpected," while Mr. Cowen also proclaimed the new skull "astonishing" in its demonstration of stasis.

Most revealing are the more subtle, linguistic clues that betray an expectation (or even a belief in the higher virtue) of continuous change. Do you not, for example, sense disparagement in Keay Davidson's description of Lucy's stasis (from the *San Francisco Examiner*), as though our earliest ancestor didn't quite cut the mustard in delaying progress so long: "The skull strengthens scientists' belief that Lucy was part of a single species that puttered around Ethiopia, evolving very little, over at least 900,000 years." In an even more revealing passage, Boyce Rensberger, writing in the *Washington Post,* expressed surprise that Lucy's brain may be no larger than an ancestral ape's, even though she lived nearly a million years after the split of our lineage from the ape bush. For here we encounter the unstated implication (another "unarticulated major premise") that a million years damned well ought to be enough time for accumulating notable change in a world of continuous alteration—although no such expectation arises in a world of stasis and punctuation, for such an interval may well lie within a period of stability. Rensberger wrote: "The newly found skull's brain capacity has not yet been measured. But it is not expected to be much more than that of a large ape, even though the creature lived at least 900,000 years after its ancestors diverged from the ape lineage."

Obviously, for a revised view about the general tempo of evolutionary change, stasis can only provide one side of a story, lest we be left with no evolution at all! The opposite and integrated side (the punctuation in punctuated equilibrium) proposes a concentration of change into relatively short episodes—jabs of reorganization in a world of generally stable systems. Enter this world at any random moment and, as an overwhelming probability, nothing much will be happening in a history of change. But survey the totality over millions of years and these episodes of punctuation, though they may only occupy a percent or two of time, build the signature of historical alteration. Scale is everything in history and geology.

The punctuations in evolutionary change are usually events of branching speciation, generally occurring in small and isolated populations within an interval (many thousands of years) that appears glacially slow at the inappropriate scale of a human lifetime, but resolves to a moment at geology's proper scale of millions. (Remember that 10,000 years—a period that encompasses all of written human history—equals only one percent in Lucy's million year epoch of stasis.)

In this light, I am gratified to see that continuing studies on the million-year period following Lucy's tenure point more and more, as data on bones and dates accumulate, to a veritable forest of rapid speciation events, leading to several additional members of the genus *Australopithecus,* and also to the first representative of our own genus, *Homo*. A chart distributed by Johanson's Institute of Human Origins to accompany their find of Lucy's son proposes as many as seven branching events within a restricted interval following Lucy's demise—a period shorter than that of Lucy's own stasis.



Adapted from Institute of Human Origins

This flowering may correspond to a time of rapid and strongly fluctuating environmental change coincident with the beginnings of glaciation at higher latitudes. My colleague Elisabeth Vrba, of Yale University, has used such evidence to unite the pattern of punctuated equilibrium with the idea that events of speciation are not evenly distributed through time, but concentrated into episodes accompanied by substantial environmental change—the "turnover-pulse hypothesis" in her formulation. Nearly all the news reports of Lucy's son also emphasized this complementary side of copious branching following the stable reign of *A. afarensis*. Many of these stories quoted W. H. Kimbel, first author of the *Nature* article: "There is no obvious sign of evolution in this pre-human species for about a million years. Yet later, within only a fraction of that time, it gave rise to a great branching of the family tree."

I began with the most famous poetic metaphor about change from Victorian England. Let me end with an even more celebrated verse about leaping, from Tennyson's predecessor as poet laureate, William Wordsworth:

> My heart leaps up when I behold
> A rainbow in the sky:
> So was it when my life began;
> So is it now I am a man;
> So be it when I shall grow old,
> Or let me die!
>
> The child is father of the man;
> And I could wish my days to be
> Bound each to each by natural piety.

If you are puzzled, I did intend this implied contradiction. Wordsworth's leap is only metaphorical; the poem expresses a hope for lifetime stability in aesthetic perception and moral value. Try his contemporary William Blake for the other side of life as rupture:

> My mother groan'd! my father wept.
> Into the dangerous world I lept.

Duality may be a conceptual prison, but if we must live with such a mental strategy, we might maximize our opportunity to grasp some of nature's complexity by hitching our star to the dyad of change and constancy. Slow and steady does not always win the race.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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The Fast Trek

by Lory Frame

At a symposium in Calgary in 1971, my husband, George, and I, a couple of green graduate students in wildlife science, joined a group gathered around George Schaller—the man who had studied mountain gorillas in Uganda and gone on to found the Lion Project in Tanzania's Serengeti National Park in 1966. Perched on the edge of a table and casually tapping one foot in the air, Schaller looked as fit and graceful as one of his lions. To us he was a star. He had been back from the field for a couple of years and must then have been correcting the proofs of his book *The Serengeti Lion*.

My husband and I thought we would soon go to northern India to study the one-horned Indian rhinoceros, but already the Indian government was imposing intolerable conditions on the research. (In fact, the project later fell through, and we went instead to the Serengeti to study hunting dogs and cheetahs.) We talked with Schaller of the difficulties of wildlife research in third world countries.

"Get yourself a pair of binoculars," he said, after listening to stories of bureaucrats seizing title to a car and politicians using a grant for something else. Setting down his empty coffee cup, he added, "Just go in, get the data, and get out."

Schaller's words came back to me as I read Craig Packer's new book, *Into Africa*. I can scarcely imagine two personalities more different than Schaller's and Packer's, yet Schaller's tersely stated objective is implicit throughout this book. Packer and his wife, Anne Pusey, are the latest and longest-lasting of Schaller's successors in the Lion Project. They have kept the project going since 1978, so they have had to go to Africa again and again. (Packer has been back recently to assess a distemper epidemic that has killed at least forty lions.)

My husband and I worked in the Serengeti from 1972 until just a couple of months before Packer and his wife arrived in 1978. We got out after a decade of socialism had reduced Tanzania's economy to shambles, and Packer started off at the bleakest possible time. One couldn't even buy toilet paper in Tanzania, and fieldwork there was definitely not glamorous.

Packer hangs his narrative on a trip he made in 1991 to Serengeti and Gombe National Parks, some 500 miles apart. Gombe is the steamy mountain rain forest where, in the early 1960s, another star scientist, Jane Goodall, discovered that chimpanzees eat meat and use tools. Packer had started his career there as one of Goodall's assistants and was now returning to initiate some new research. The entire trip lasted fifty-two days, but of that time, Packer spent all or part of twenty-two days en route. Hold on to your hat.

From the very first lines of the book we know Packer isn't thrilled to be going back to Africa (his sixteenth trip). But as the boxes and bottles in the car shake and tip over, as the passengers stop to repack the car and have some binoculars stolen, as the texture of dirt, noise, delay, and frustration is developed, we begin to understand what it is really like—for Packer anyway—and we know he did not come to Africa for this.

After spending four days traveling and meeting the necessary people, Packer finally reaches the heart of the Serengeti National Park—the Serengeti Research Institute (SRI), where Schaller did his work. He spends only eight days there and another eight after returning from his trip to Gombe. Packer recounts his first sighting of lions in an oddly matter-of-fact and unadorned manner, considering the trouble he had getting to the Serengeti. He is preoccupied. He has a very angry assistant at SRI who won't hand over forty lion scat samples. And his attempts to worm some lions for his graduate student are unsuccessful. (She longs for some adult worms to take home to her laboratory in Oxford.)

INTO AFRICA, by Craig Packer. *University of Chicago Press, $24.95; 288 pp., illus.*

Go in, get your data, and get out. But in only sixteen days?

Packer takes us through the process of hypothesizing, testing, and revising prior assumptions about lions. For example: Female lions nurse one another's cubs. Would a female ever short her own cubs to let others drink? Test it. Do cubs get more to eat in "crèches" than they would if their mothers raised them separately? Test it. Do the mothers eat better, for that matter, if they hunt in large groups? Test it. As Packer ponders, tests, and rejects one hypothesis after another, we feel ourselves drawn closer and closer to why he keeps coming back here.

"I study the darkness," Packer says, by which he means that animals often behave appallingly toward one another. Why do males kill cubs (that are not their own offspring) after they take over a new pride? Because the mothers won't cycle again until the cubs are two years old, and the

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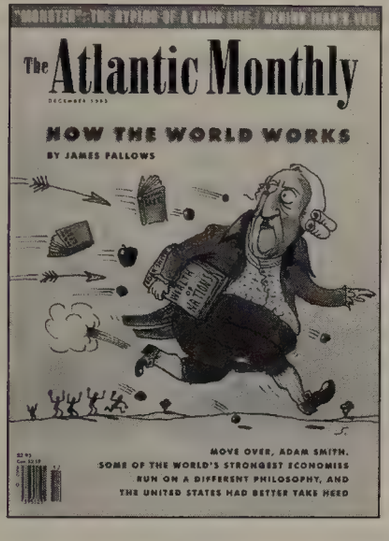

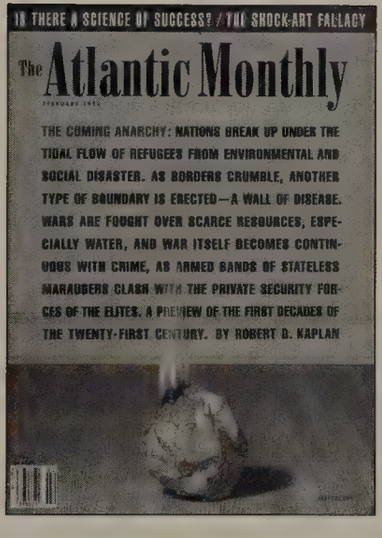

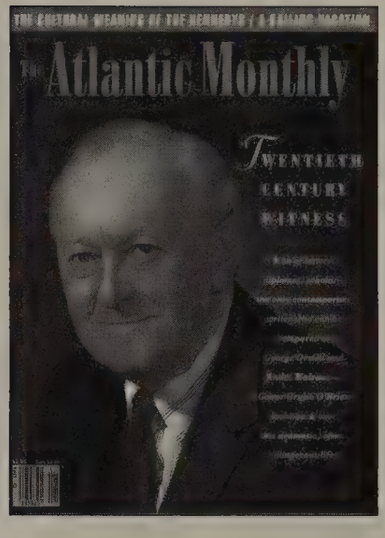

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males that have just taken over a new pride cannot afford to wait that long: the average sojourn of males in a pride is only about two years. Get those genes into the next generation. Kill the cubs, and bring the mothers into estrus immediately. "Every lion in the world has a father who is a murderer," Packer says. (Oddly, he does not explain why nomadic females also kill cubs, a phenomenon Schaller observed.) His essays on the self-interest that underlies all animal behavior are lucid, unsentimental, and intellectually compelling. *Into Africa* serves up animal behavior correctly: as a savory dish that would be ruined by sugar. Those with immature palates may not like it, but grown-ups will.

In Part II, Packer flies to Dar es Salaam and then to Kigoma, where he gets a boat to Gombe:

> In the murk, even after all these years, I can recognize each valley: Kahama, Mkenke, now Kakombe. We draw closer to land, chugging past square concrete buildings shrouded by trees and shrubs, past the sheet metal house where I used to live. Anthony cuts the engine, and we are engulfed in sudden silence. The boat grinds on the gravel beach in front of Jane's veranda. Warm lake water laps at our legs as we drag the hull onto the silver shore. I walk a few yards away and stare into the empty night, nervous of the shadows in the dark. Even after all these years.

Maybe his description of Gombe is so vivid because a terrible thing that happened there still haunts him. One dark night in 1975, a boatload of Marxist rebels motored across the lake from Zaire and kidnapped four young researchers. Packer and his wife were fortuitously away on holiday or they would have been taken too. When they returned, they were given a half-hour to collect their things and get out. This event was not only a personal disaster for the captives and their families but also the death of Gombe as a research center for the next fifteen years. Now, with a grant from the National Science Foundation to initiate new research, Packer is back, but he is not entirely comfortable in this unhealthful place. After setting up a method for weighing chimps, hurriedly mapping the palm groves in the chimp community, and waiting for his student to get samples of baboon feces, he is glad to leave. Go in, get the data, and get out.

In Part III, Packer stops briefly at the Ngorongoro Crater on the eastern edge of the Serengeti, camping at Lerai Cabin, where my husband and I lived for a time. (Fortunately, he didn't notice the ghastly—but only available—color of paint we'd used on the inside walls.) The crater's lion population was nearly exterminated by a plague of biting flies in 1961. A few surviving females founded the population that lives there today, and Packer is interested in the effects of this loss of genetic variability.

Soon Packer is back at SRI to attend a meeting organized by Anthony Sinclair, one of the original SRI scientists of the 1960s and now a professor at the University of British Columbia, and Peter Arcese, who studies ungulates in northern Serengeti National Park. They want to devise a computer program of the entire Serengeti ecosystem that could generate predictions of the park's condition if this or that variable (such as rainfall) were to change. Naturally, the effects of the various predator species on the prey and on one another would be important. Serengeti's current predator specialists are at the meeting but appear to be unhappy about it, like children who have been told to play nice and share their toys. "Participation," Packer comments dryly, "has not been wholehearted."

The scene brings back a memory of the mid-1970s when my husband and I worked at SRI. Tony Sinclair breezed into Seronera and encouraged us to do a survey of predator numbers on the plains. Everyone working at SRI was drafted, and there were one or two who resented it.

Packer senses similar recalcitrance fourteen years later. Scientists get to SRI with their own grants, so the interests of the "SRI community" may not rank as high as one's own research. The computer model was obviously not of equal value to everyone. Self-interest exists in humans as it does in lions or chimps or any other creature. The darkness in our hearts, as Packer thinks of it, is what gets in the way of productivity and the common good.

Into Africa is a new kind of animal behavior book. Prior authors have dwelt contemplatively on the minutiae of an animal or a place; Packer doesn't pause very long anywhere and this gives the book an engaging briskness. Another difference is that readers don't have to love animals to find this book engrossing; all they need is curiosity. Packer himself is intrigued, not by animals themselves, but by the things they do. At random, I opened the book at twenty places and found only six pages on which animals were even mentioned. This book is really about someone who studies lions, what he thinks of his fellow humans, what he notices about modern Africa, and what he gets done in spite of difficulties.

Packer is introducing us to his Africa, giving us pithy, gossipy (in spots), occasionally whimsical descriptions of its people, history, researchers, bureaucrats, politics, shops, journeys, sounds, and smells.

I especially like the credit he gives to Barbie Allen, a woman whose father settled in Kenya after World War I. She had raised her own family of four there, and then extended her beneficence to include itinerant scientists. Since the 1970s she has operated what we call the "other SRI" from her home in Nairobi. Given the difficulty of living and working in Tanzania, Barbie's support was not just appreciated, it was critical. Many a sick scientist—sick in body or maybe just sick at heart—got well again under her roof, instead of having to repair all the way home to Europe or the States.

I remember one afternoon on the plains when I was hot, dusty, and exhausted after four days on safari. I saw a little dust cloud coming closer and closer until the dark spot of a vehicle could be seen at the bottom of the plume. Finally, as the car pulled up and some people got out, I recognized Barbie. She had loaded the car with fresh vegetables and the cooler with meat, none of which we had seen in three months. "We just thought we'd take a drive," she said, casually introducing us to her companions. A "drive" of eight hours. Not everybody acts out of self-interest, and Barbie is proof.

What keeps Packer coming back again and again into unhealthful, inconvenient, frustrating Africa? To get his data and get out. What does he do with his data? "I would like to believe that by understanding the nature of selfishness," he says, "we may someday understand the best way to divert that selfish energy to the common good." All right, but here is another reason, and most scientists will recognize it:

Everything kept falling into place…the lions fit the same pattern, a pattern no one had ever noticed before.… To feel that you have discovered something important about nature is intensely exciting. When the feeling hits, I can hardly sit still. My mind is on fire; the excitement sustains me over these rough, dusty roads, illuminates my cold winter days in Minneapolis.

Lory Frame studied African hunting dogs in the Serengeti and warthogs in Burkina Faso. With her husband, George Frame, she coauthored and illustrated Swift and Enduring, *an account of their hunting dog and cheetah studies. When not in Africa, she writes from her home in Grassy Sound, New Jersey.*

Rough Rookeries

Baby sea lions soon discover that their adult neighbors can be killers

Text and photographs by Fred Bruemmer

In Rudyard Kipling's story "The White Seal," a mother fur seal warns her pup:

> You mustn't swim till you're six weeks old,
> Or your head will be sunk by your heels;
> And summer gales and Killer Whales
> Are bad for baby seals

That is good advice for most seals. But in four out of the world's five sea lion species, the most common danger to pups comes from their adult kin. Infanticide, accidental or intentional, is a major cause of pup mortality.

Eight-hundred-pound Hooker's sea lion bulls will galumph blithely across just-born twelve-pound pups or absent-mindedly sit on a pup and squash it. Young male southern sea lions sneak in among females on a beach, kidnap pups, use them to practice herding and harem keeping, and sometimes kill them. Steller's sea lion cows can be fierce toward pups other than their own; they bite, shake, and toss "alien" pups that come too near. And Australian sea lion bulls attack pups with concentrated, lethal fury, biting and shaking them as a terrier shakes a rat, and leaving them mangled on the beach. In this species, about 20 percent of pup mortality is due to attacks by adult males.

The Hooker's is the rarest and probably the most mild-mannered of all sea lions (seal scientists refer to them fondly as "the gentle Hookers"). Most breed in the Auckland Islands, 300 miles south of New Zealand. I observed them for several months on Enderby, the northernmost island of this group where, during the austral summer, about 600 sea lions mass on the broad, half-mile-long breeding beach.

The males arrive in early November and after some violent fights, the strongest bulls divide the beach among themselves. For nearly a month they all are males-in-waiting, each jealously guarding his empty circle of sand. The females come to the beach in early December, settle upon the territories of the waiting bulls, and a few days later give birth to pups that were conceived the previous year.

Hooker's sea lion bulls fight on Enderby Island, off New Zealand, while a pup scurries out of harm's way.

After herding pups into a "harem," below, a subadult Hooker's sea lion bull rests on the beach. A sleeping female Hooker's sea lion, right, nurses her own pup, as well as an orphan that has settled in to feed.

Shortly after the birthing season, with many females about to reenter estrus, the bulls are most excitable and the just-born pups most vulnerable. The bulls I watched were not actively hostile to pups and never attacked them. They completely ignored them; for all they cared, the pups might have been lumps of sand upon the beach. In their jealousy-prodded charges, however, the bulls simply trampled any pups that got in their way. While the females did their best to shield the youngsters, they were rarely fast enough or strong enough to deflect a charging 800-pound male.

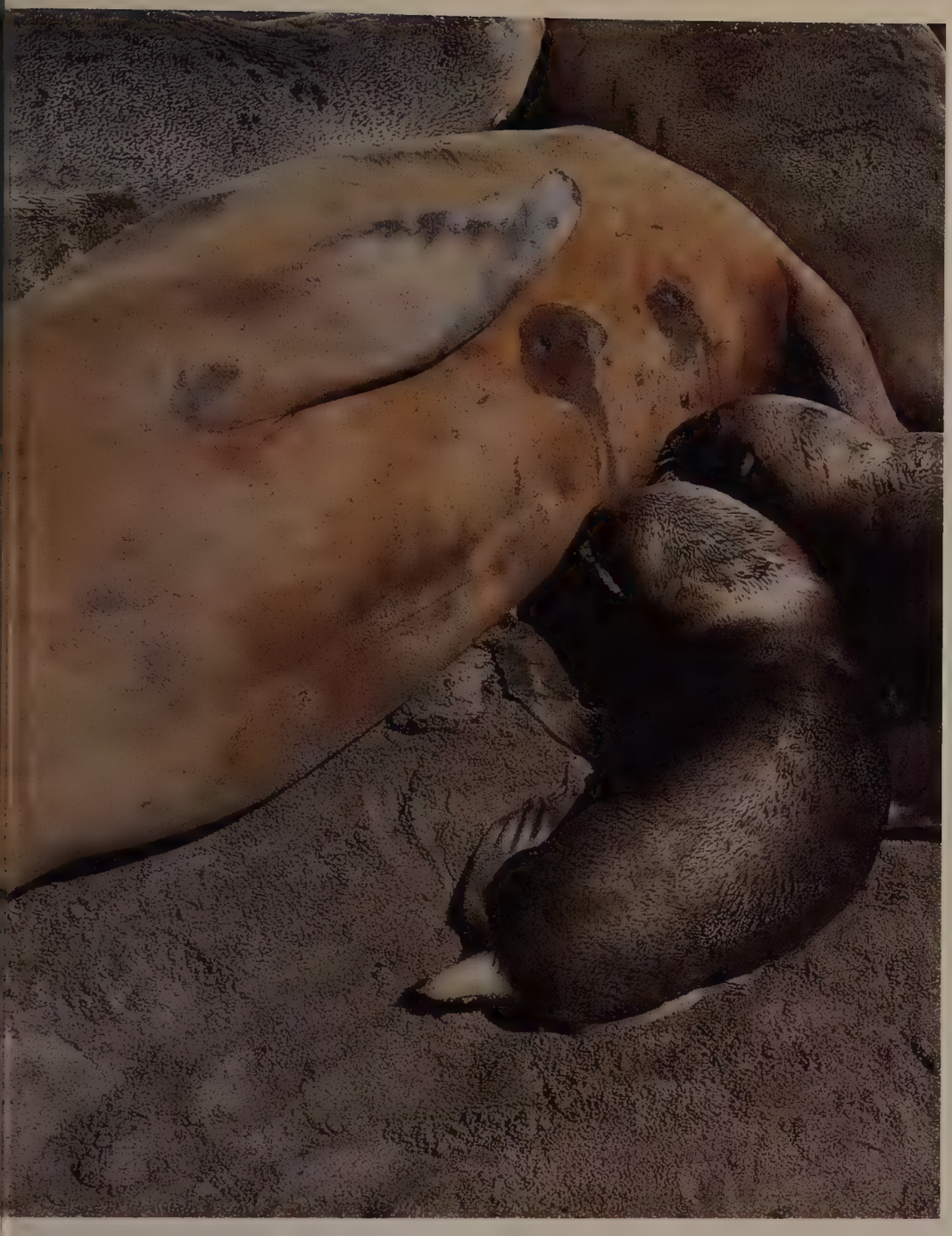
The sand is soft, and the pups are amazingly resilient; most survived being steamrollered by the great bulls. The greatest danger to pups was not a passing bull, but one that halted abruptly right on top of the pup. It would sit there, a massive hulk, totally oblivious of the tiny creature squirming beneath it. Most females tried frantically but ineffectually to free their pinned pups: if a small flipper protruded from beneath the bull, they pulled it, usually without success. They never bite the bulls, but New Zealand sea mammal expert Martin Cawthorn watched a female use a shrewd stratagem to free her pup. She moved provocatively in front of the bull and presented herself for mounting. The bull moved instantly to the female, who repelled him, nuzzled her freed pup, and led it to safety.

Three percent of all pups born on Enderby Island are accidentally crushed to death by rampaging bulls. The pups are quick and precocious, however. Within three or four days of birth they know the danger of a big bull and quickly scramble out of the way when one comes barging along. Within ten days, the surviving youngsters leave the dangerous regions of the beach and gather in safer areas.

Female pinnipeds (sea lions, seals, and walruses) usually nurse only their own pups and repel all others. The placid Hooker's sea lion cows generally adhere to this rule, but with certain exceptions. When females go to sea to feed, for instance, their pups, hungry after a day or two, shuffle off in search of milk. Typically, a hungry pup sidles up to another suckling pup to drink quietly from a sleeping mother's teat. When the female awakes, she growls at the intruder, the pup backs off, the cow goes back to sleep, and the pup resumes its interrupted meal. Cows snarl and snap but do not hurt the milk moocher; the youngster's risk is minimal and the reward worth it. I once saw a female nurse four pups.

Immature Hooker's sea lion bulls are a nuisance to the pups, but they do not attack them. These three- to five-year-old males are the restless ruffians of the beach, constantly play-fighting with one another. Sometimes they try to mount adult cows, are noisily repelled, and have to flee from charging territorial males—thereby endangering any pups in their path. Young males may also use pups as female substitutes: they herd them, try to form and keep pup "harems," and occasionally attempt to mate with squirming, protesting pups. But they are not brutal, and when pups are really fed up, they quickly escape.

Southern sea lion pups are less fortunate. During a four-year study conducted at Peninsula Valdés in Argentina, by Claudio Campagna, of the University of California, and his colleagues, immature male



sea lions seized pups on 285 occasions. Some were individual kidnappings, while other incidents were raids carried out by several subadult males acting together. While adult male and female southern sea lions do not injure pups, the subadult males "appear to use pups as female substitutes to redirect their frustrated sexual and aggressive motivations," according to Campagna. During his study, 5.6 percent of the abducted pups and 1.3 percent of the pups born each year died from injuries caused by subadult males.

Among Steller's, or northern, sea lions, the female is a threat to pups. I studied the behavior of this species during two seasons in the early 1980s on Marmot Island, off Kodiak Island in Alaska. The largest of all sea lions, adult males grow up to twelve feet in length and weigh more than 2,000 pounds, and adult females can be nine feet long and weigh nearly 800 pounds. Sadly, the Steller's sea lion populations have drastically declined in Alaska. In 1961, the total Steller's sea lion population was thought to be between 240,000 and 300,000. Thirty years later, in 1991, only an estimated 40,000 were left. Lack of food fish due to overfishing by humans seems to be a major reason for this rapid decline.

During my field studies at Marmot Island a decade ago, more than 10,000 sea lions crowded the seven rookeries and each season about 5,000 pups were born. Now many beaches are empty; fewer than 3,000 sea lions were counted during recent summer breeding seasons there.

At Marmot Island the bulls arrive in May and after many fights divide the beaches among themselves, top territories going to "beachmasters"—eight- to ten-year-old males in their prime. Their choice of sites seems to accurately anticipate where the females will cluster. The females arrive about two weeks later, and also claim spaces according to their places in the social hierarchy, with the most sought-after spots going to the older cows.

A few days after their arrival at the rookeries, the females bear pups that face a rough initiation into the world. The moment a pup is born, its mother raises it a few feet above the beach and drops it onto the rocks—the sea lion version of a slap on the bottom. She repeats this behavior (one scientist observed a female picking up and dropping her newborn pup fifty-two times in a row) until the pup is crying and crawling. Then the female sniffs her pup and listens intently to its voice; from this moment on she can pick out her baby from all others on the beach. The hardy, forty-pound pups easily survive this rough handling, but some face another danger. At times, the previous year's pups overwhelm the mother with their importunate nuzzling and crying for attention. Distracted, she may fail to bond properly with the newborn, and might even attack it as if it were a stranger. In some cases, where 150-pound yearlings monopolized a mother's attentions, the newborn pup died in a day or two.

The main danger to Steller's sea lion pups, however, is not from their mothers, which are intensely maternal and protective, but from other, unrelated cows. Most females are fiercely hostile to all pups that are not their own. During its first week of life, a pup does not recognize its mother's voice and may crawl hopefully toward any calling cow on the crowded beach—a move that can be fatal. If a female, upon sniffing the pup, decides it is not hers, she snarls and tosses it yards away. Landing in the private space of another cow, the pup may be grabbed and flung again, then thrown back and forth by hostile females, like a screaming, flippered rag doll. Most survive this brutal treatment and learn to recognize their mother's voice, for there is no milk-mooching in this species.

Even more dangerous for a pup than a run-in with the wrong mother is an encounter with a female that has lost her own

youngster. On Marmot Island, I watched several cows seeking and calling for their lost offspring. Such a female rushes eagerly toward any pup that responds and sniffs it hopefully. If it turns out to be the "wrong" pup, the frustrated female bites and flings the pup, rushes after it and bites it again, and may maul it until it is dead.

In size and appearance, Hooker's sea lion, of subantarctic and New Zealand waters, and the neighboring Australian sea lion are similar. In temperament, however, they are totally different. Hooker's are placid and pacific, while Australian sea lions are excitable and belligerent. The Australian scientist B. J. Marlow, in the first comparative study of these two species, published in 1975, characterized the social behavior of the Australian sea lion as extremely aggressive in both sexes of all ages. In contrast, the Hooker's appeared "extremely benign."

Australian sea lions differ in another, vital way from other pinnipeds. Most pinniped species have a twelve-month reproductive cycle, during which adults return to their ancestral breeding grounds at a specific time of the year. Females give birth shortly after arrival and mate again a few days later. Within weeks, adults and young leave the rookery sites and return to the sea to follow their favorite prey.

Only the Australian sea lion has an asynchronous, eighteen-month breeding cycle. Females can come to breeding beaches and give birth at any time of the year. In a recent paper, Australian scientists Nicholas J. Gales, Peter D. Shaughnessy, and Terry R. Dennis speculate that the Australian sea lion's irregular reproductive cycle is an adaptation to an equitable climate and a depauperate sea. By staggering births, the lactating females' demands on the local seas' limited food resources is spread over the entire year.

Among other sea lions, top bulls have harems, while each high-ranking Australian male usually keeps only one female. If a subordinate male approaches, the guardian bull quickly chases him away and then, huffing and snorting, returns to his post near the female. When an equal-

On Australia's Kangaroo Island, a male Australian sea lion bull, left, top, pounces on a pup that has emerged from hiding among the rocks. The male shakes the pup violently, center, then flings it away. Finally, after several fierce attacks, the bull has killed the pup, bottom.

Although devotedly maternal to her own pup, a Steller's sea lion cow on Marmot Island, Alaska, attacks and bites any "alien" pup that comes too near.

sized male encroaches on the female, a violent, often bloody fight ensues. The huge males face each other, hacking and parrying. Often one may grab a thick fold of skin on the neck or flank of his adversary, jerk and heave and—like a sumo wrestler—try to lift the opponent off the ground. Fights last until the lighter, weaker animal turns and flees.

Wrestling and intimidation among mature males is normal sea lion behavior. But biologists are puzzled by what seem to be aberrant attacks by bulls upon pups. Australian sea lion females, unlike females of other sea lion species, will bite bulls that come dangerously close to their pups. As B. J. Marlow has observed, however, this defense is usually ineffectual. Some females may even attempt to defend pups that are not their own from rampaging bulls. Australian sea lion pups have come to fear all adults, except their mothers, and flee at their approach. Before a female goes to sea to feed, usually ten days to two weeks after parturition, she hides her pup in a niche or crevice or beneath piled boulders where a bull cannot reach it. As Marlow observed in 1975, this strategy favors meek pups that obediently remain concealed, while the curious, venturesome pup that comes out and explores is most likely to be caught and killed by a bull. "It is difficult to visualize the adaptive advantage of a social system which causes high pup mortality from adult aggression," Marlow wrote, "and which would appear to favor timid and nonexploratory behavior in pups."

Before the season at Seal Bay on Kangaroo Island off southern Australia, I had read the scattered reports about such attacks, but nothing in the dry, detached scientific literature had prepared me for the malefic ferocity of a bull intent on killing a pup. Here is one sequence of behavior that I witnessed during the austral summer of 1992–93.

A female about to give birth had come from the sea and picked a spot near the cliff that rose at the back of the beach. Another female, now at sea, had hidden her three-week-old pup among the boulders at the base of this cliff. Within a few hours of her arrival, a top bull had found the pregnant female, guarded her with possessive vigilance, and fended off the attentions of several encroaching males. Three days later, a young male tentatively crossed into the exclusive sphere of the resident bull, only to be attacked. For a moment the ri-

After feeding at sea, a female Steller's sea lion sniffs a pup to be certain it is her own.

vals faced each other, then the young bull turned and fled. The huge bull, seething with unspent fighting spirit, his mouth wide open and vibrissae abristle, waddled back to his post.

At this moment, the long-hidden pup emerged from its refuge among the boulders. Probably hungry, it may have mistaken the pregnant female for its mother. When the bull saw the movement, he immediately lunged forward and grabbed the pup before it could flee. The pregnant female attacked and bit the bull, but to no avail. He shook the pup, flung it ten feet, rushed after it, grabbed it, and shook and tossed it again. Each movement of the desperate youngster incited the bull to new attacks, until the pup lay dead.

Eventually, the beach's resident Rosenberg's goanna, a five-foot-long monitor lizard that patrolled the area for carrion, fed on the carcass. Leslie V. Higgins, of the University of California, who studied Australian sea lions at Seal Bay in 1986–87 and again in 1988, recorded eight attacks by bulls on pups, four of which were fatal, and felt that "misdirected aggression" by bored bulls is the most likely explanation for the behavior.

Harem bulls of other sea lion species defend extensive territories, fight frequently with rival males, and mate often. In contrast, the Australian sea lion male has a much smaller territory to defend, and it is occupied by only a single female. Days may pass without a fight, until anything that moves—and that is usually a pup—becomes a target and victim of the bull's pent-up aggression.

Other attacks on pups followed a similar pattern but not all resulted in death. I observed one large male that came upon an older pup playing in a shallow rock pool. He pounced on it and bit it, but as he tried to get a firmer hold, the pup twisted free and escaped.

Interestingly, the "ferocious" Australian sea lion males kill about 3 percent of the pups born in their rookeries—the same percentage destroyed by the "gentle" Hooker's bulls, with their proclivity for accidental tramplings. □

A king vulture in Costa Rica adopts a threat posture. These birds are the largest and most powerful of the New World forest vultures.
Erwin and Peggy Bauer

To the Vultures Belong the Spoils

In New World rain forests, scavenging specialists win the carrion sweepstakes

by David C. Houston

The carcass of a howler monkey, half buried by leaves and debris, lay in the darkness of the forest floor in northern Venezuela. Homing in on the corpse, a turkey vulture landed beside it. Within minutes, another touched down, keeping its distance as the first nosed the prize and scratched the earth around it. Two more turkey vultures remained airborne near the treetops. They were, perhaps, warned away by rapid changes in the hue of the bald red heads of the birds on the ground, which can signal dominance within their species. A couple of black vultures, however, were less inhibited and soon took their place next to the carcass.

Work on the dead monkey was barely under way when a king vulture easily exerted its dominance over the other birds and took charge. While the black vultures squabbled in the background, the king grasped the monkey with both feet and tore through its skin and into the tendons. Now the softer tissues of the dead animal were exposed, making access for the other species easier. The black vultures unraveled the intestines, while the turkey vultures, more dainty feeders, poked within the carcass for small bits of meat, often using one foot as an anchor. Gradually, scraps clinging to bone or scattered on the ground were plucked and devoured, completing the cleanup. The turkey vultures were the last to leave.

In a grassy area on the edge of the forest, the ample corpse of a domestic cow was attracting scavengers. Once again, turkey vultures were the first on the ground, followed closely by black vultures. Because they often hunt in family groups, black vultures quickly draw in more of their kind. (The record for this area is more than 200 black vultures at a single carcass.) Their gathering numbers easily displaced the turkey vultures, which waited on the sidelines. The cow's body, its hide softened by decomposition, was ready for the black vultures. They began to feed on muscle and viscera that could be extracted with little force. Any suitable hole in the skin was an invitation for the black vultures to climb right into the roomy carcass, full of meat that could not be reached from the outside. Again the turkey vultures polished off small, remaining bits of carrion.

No less an observer than Charles Darwin, who had seen the turkey vulture in South America in the 1830s, described it in *The Voyage of the Beagle* as a "disgusting bird, with its bald scarlet head formed to wallow in putridity." But the features that struck Darwin as repellent are the hallmarks of a supremely efficient scavenger. The ways in which vultures make their living from death, and the ecological roles they play in tropical forests, have been the focus of my research for the past few years. This work has taken me to rain forests in Brazil, Venezuela, and Panama.

While extremely similar in appearance to Old World vultures, New World vultures are not related to them. The vultures of Africa, Asia, and Europe are descended from the same ancestor as are eagles and hawks. New World vultures, including the California and Andean condors, share a common ancestry with the storks. The two major vulture groups are thus textbook examples of convergent evolution: two unrelated groups of animals that resemble each other closely because they have developed the same adaptations for a similar way of life. In the case of vultures, these adaptations include bald skin on the head and neck, which helps to prevent feathers from becoming soiled and also aids in heat regulation. Vultures are also superbly adapted for soaring flight, having large, broad wings. All vultures make their living by scavenging dead animals. While black vultures do sometimes kill weak animals, the other species have virtually lost the ability to kill their own prey and survive only by finding carrion.

The Old World vultures differ from their Western Hemisphere counterparts in that they live exclusively in open areas—grasslands, savannas, and deserts. New World condors inhabit mountainous regions, and some other New World vultures range into a variety of landscapes. However, the greatest diversity of New World vultures—five species—is found in Central and South American tropical rain forests. Of these, the turkey vulture is the most widespread; in winter, the resident tropical race is joined by migrant turkey vultures from North America. The lesser and greater yellow-headed vultures are close relatives of the turkey vulture; the lesser is a denizen of open areas near the forest edge, while the greater is strictly a forest bird. Black vultures range throughout South America, usually inhabiting forest edges and the outskirts of villages and towns. Finally, the king vulture, the most spectacular and powerful of the forest scavengers, is still widely found in undisturbed areas. In and near forests, these vul-

Their long, broad wings allow vultures to soar and glide over great distances, right. Such effortless flight is an advantage when carcasses—their source of food—are few and far between. Below: A young turkey vulture in Panama lingers by the picked-clean bones of a chicken.

David C. Houston

tures are abundant. They average up to two birds per square mile, a density probably greater than that of any other carnivorous bird.

The tropical forest would appear to be a difficult place for high-flying birds to spot a potential meal. Virtually all plant growth is in the lush treetops. In some places, the dense canopy allows less than one percent of sunlight to reach the ground, so relatively few plants and animals thrive in the dark understory. Sloths and monkeys, the most abundant forest mammals, live in the canopy. Apart from an occasional snake and monkey-eating eagle, big predators find treetops a risky place in which to pursue prey, and most canopy-dwelling mammals probably die of disease, parasites, accidents, old age, or food shortages, rather than predation. On average, in healthy forests with thriving mammal populations, one animal dies in each square mile every day.

When a monkey or sloth dies, it falls, crashing down perhaps some seventy feet through the dense canopy foliage, then through the shrub layer, to land in the deep shade of the forest floor. Often covered by leaves and debris thrown up on impact, the body, if it can be located, represents a windfall of protein for other members of the forest community. A dead animal will attract typical ground predators, such as jaguars, ocelots, and tayras, as well as armadillos, opossums, and coatis; even forest tortoises relish a meat meal when they can find one. Carrion flies and beetles, which lay eggs or even live maggots on carrion and rely on it as a source of food for their larvae, constantly scour the forest floor for corpses. Maggots pour digestive enzymes into soft tissue, breaking it down into a fluid that they then suck into their gut, absorbing the nutrients. Aided by the heat and humidity of the rain forest, they can reduce most of a small monkey carcass to a skinful of mush within three days. From a vulture's point of view, finding a carcass is a race against time. Not only do vultures have to beat mammalian scavengers, already on the ground ready to follow a scent trail to the prize, but they also have to find the body before insects render it an inedible, maggot-ridden soup.

To find out more about the competition for carrion, I conducted a series of experiments at seven different forest sites in South America, putting out chicken car-

Aldo Brando

A large snag in a Brazilian forest serves as a perch for a greater yellow-headed vulture, below. These vultures, and their close relatives the turkey vultures, have a keen sense of smell.

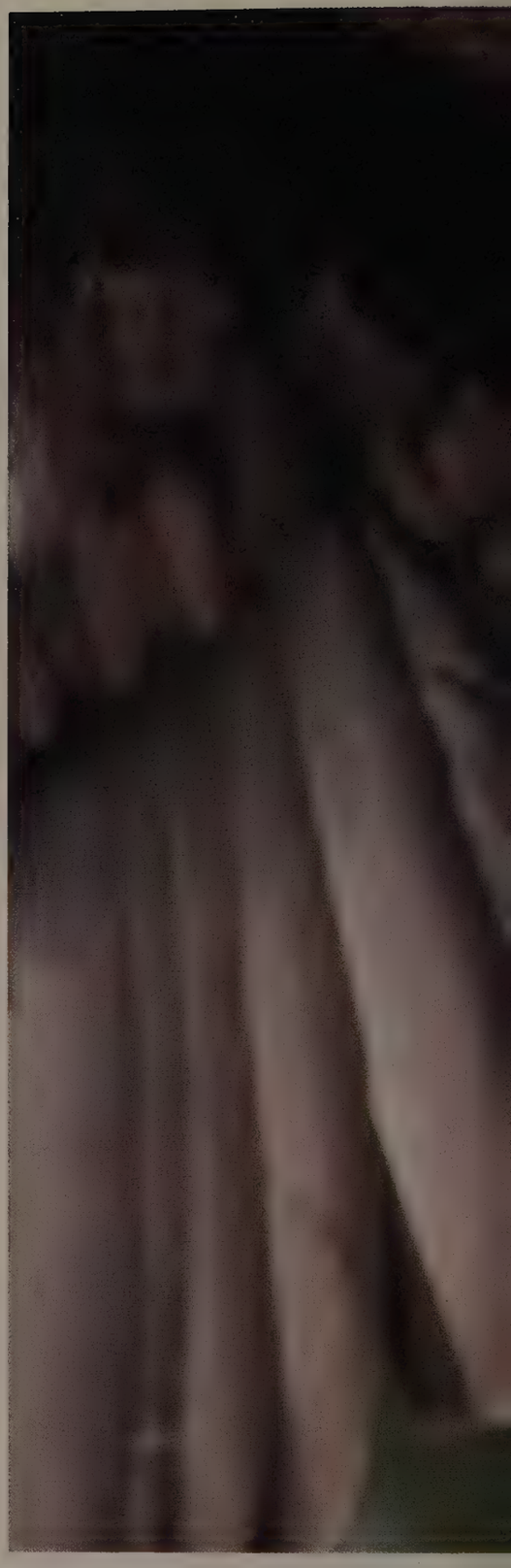
Luiz Claudio Marigo

casses and then monitoring which animals came to feed from them. Between 60 and 95 percent of all the carcasses I provided were taken by forest vultures. Yet, unlike their insect and mammalian competitors, vultures have to search from above the tree canopy. How do they home in on carrion so swiftly?

Birds are often assumed to have no sense of smell at all, and in most birds, this sense is indeed poorly developed. In a few species, however, olfaction is acute. The kiwis of New Zealand, for example, nose out earthworms in the soil, and the ocean-going shearwaters are able to detect fish and plankton shoals by faint traces of fish oils in the water. Kenneth Stager, of the Natural History Museum of Los Angeles, was the first researcher to carry out carefully controlled experiments that demonstrated that turkey vultures were attracted by the scents given off by carrion; and Betsy Bang, of Johns Hopkins University, has shown that the brain and olfactory region in the skull of these birds is exceptionally well developed.

The turkey vulture's total dependence on its sense of smell to find food in the forest can be easily demonstrated by putting

Thomas Kitchin; First Light



If the hide is too tough to penetrate, a carcass, such as that of a steer, below, can present a problem to black vultures. The birds tend to take advantage of any available opening or exposed soft tissue.

Kevin Schafer and Martha Hill

out carcasses, some left uncovered and some hidden completely by a pile of leaves. The birds find the hidden carcasses just as quickly as those in the open. Turkey vultures hunt by flying just above the level of the tree canopy, sniffing the air all the time. As soon as they get a whiff of rotting meat, they start to circle to determine where the aroma is strongest. They then fly down into the forest, following the scent trail from tree to tree, until they are led to their reward on the forest floor. Because an airborne bird on the scent is usually within sight of many others that are quick to follow, good numbers of vultures of various species can congregate at a carcass within minutes.

A dead animal takes some time before it begins to smell strong enough for a turkey vulture to detect it. To find out how long, and to test the smelling ability of vultures, I placed a series of dead chickens in the forest in Panama: some were freshly killed, others were a day old and smelling slightly, still others were several days old and really stinking. Turkey vultures could not detect carrion less than about twelve hours old. A carcass twenty-four hours old, however, emits a sufficient stench to attract vultures readily.

These birds have a reputation for savoring stinking, rotting meat, but when offered a choice of relatively fresh or rotting meat, they strongly preferred the fresh. This is probably why the earliest investigations into whether turkey vultures had a sense of smell reached the wrong conclusion. In 1826, John James Audubon published the results of a series of feeding trials that he had carried out on turkey vultures, from which he concluded that they had no sense of smell at all. But Audubon had based his experiments on the assumption that vultures would be particularly attracted to foul-smelling food, so he had sought out the most rancid old fish and dead dogs to use for his baits. Not surprisingly, vultures failed to arrive. I am sure that they could smell his rank baits perfectly well but preferred to keep on searching for more wholesome fare.

Badly decayed meat contains unpleasant bacterial compounds that either impede digestion or are actively toxic. Dan Janzen, of the University of Pennsylvania, has suggested that many of the products of bacterial and fungal growth in foods have evolved specifically to render the food inedible to larger animals, so that microorganisms do not have their food supply stolen from them. Vultures will eat rotten meat if they are extremely hungry—as would any starving animal—but if they are not short of food, they will give bad meat a miss and wait for the scent of something more palatable.

Turkey vultures can tell from the smell coming through the tree canopy how long an animal has been dead, probably because the smells given out by the bacteria that develop in meat change with the age of the carcass. Thus, vultures do not even bother to fly down to old carcasses as often as they do to day-old carrion. Even the human nose can detect the level of decay. I soon learned to tell the age of a chicken carcass from its smell—fortunately not a skill I need to use very often at home. But our ancestors, who probably

Like all other vultures, the turkey vulture, above, has a bald head. Bits of carrion do not adhere to the skin as they would to feathers. When a king vulture is present, left, even a crowd of black vultures will defer to it. Here a king, using its superior strength and more formidable beak, rends a carcass.
F. Köster; Survival Anglia

Patricio Robles Gil; Bruce Coleman, Inc.

Faced with the armor on the back of an armadillo carcass, a king vulture attacks the underbelly and entrails, below. A turkey vulture, right, sunbathes on a palm tree in the Yucatán Peninsula.

Carol Farneti; Planet Earth Pictures

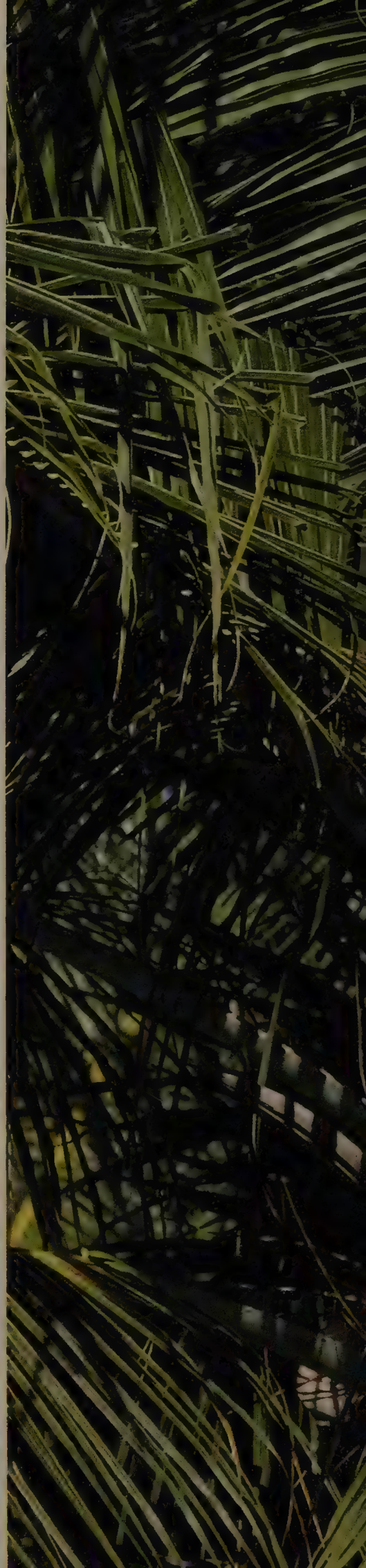
scavenged as well as hunted for their food, may have found this ability useful.

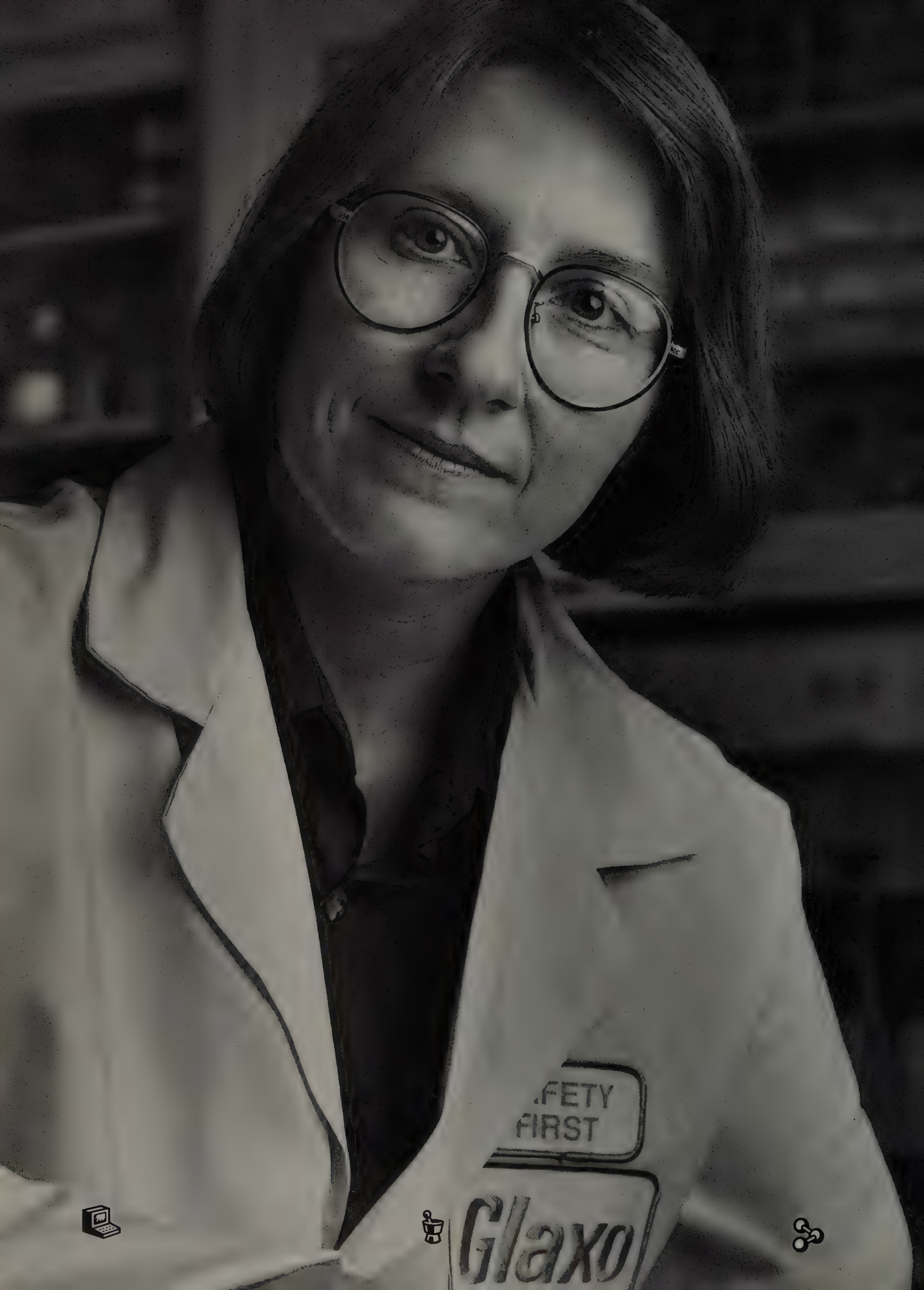
Only turkey vultures and lesser and greater yellow-headed vultures can locate food by smell; black and king vultures (and, incidentally, the condors) lack this ability completely. Their technique is to fly at high altitude and keep an eye on the turkey and yellow-headed vultures flying below them, just at the level of the tree canopy. As soon as they see these birds circling and starting to congregate, they descend and join in the feeding party.

Because both black and king vultures dominate other vulture species, they tend to take over the carcass for a while. The presence of different species at the same carcass poses little problem, however, because each species specializes in a method of feeding. King vultures are the only ones powerful enough to tear through tough skin and open up a carcass for others. Black vultures tend to concentrate on the blocks of viscera and muscle, while turkey and yellow-headed vultures feed more slowly and can tear off the last scraps of meat from the bones.

At first I was surprised at how few of the carcasses I set out were discovered by scavenging mammals. Yet the vultures' dominance as South American forest scavengers makes sense when considered from the standpoint of energy expended versus energy consumed. Dead animals are scarce and ephemeral, and their whereabouts are unpredictable. Even with an acute sense of smell, mammals have to search by walking or running—energetically expensive ways to travel, particularly if a food supply is irregular. No species of mammal has ever evolved as an exclusive scavenger, while many bird species have done so. Birds' traveling costs are minimal. All vultures, for example, are supremely adapted for soaring flight. Many species scarcely flap their wings in the course of a day; instead, they glide, taking advantage of rising air currents to stay aloft. They can cover long distances at high speed, using little energy. A soaring vulture can afford to spend much of the day airborne, covering hundreds of miles in search of scarce carcasses.

The most successful of New World tropical forest scavengers, vultures are also the major meat-eating animals in the forest community, consuming more than all mammalian predators put together. The job of recycling the animal riches of the rain forest falls mainly to them. Although they may not win any beauty contests, vultures carry on their roles in the rain forests with quiet efficiency, and to my eye, with a certain adaptive elegance. □

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No Pain, No Game

For the Mayoruna and Matses of the Amazonian forest, preparing for the hunt can be an ordeal

by Katharine Milton

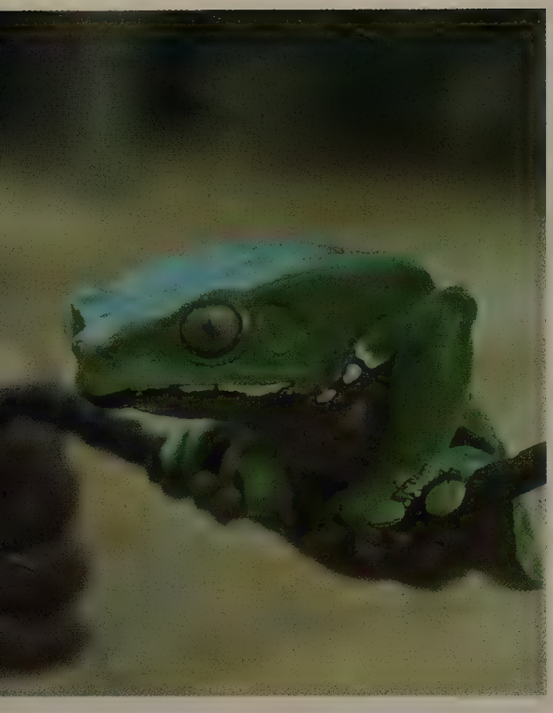
Early in my study of diet and ecology in Lobo, a village of 110 Mayoruna Indians in Brazil's Amazonian forest, I noticed that the men and adolescent boys had neat rows of small scars on their upper arms and chest. At first I thought these might be the result of cigarette burns, and although this seemed a bit odd, I didn't really question my interpretation until it dawned on me that the Mayoruna had no cigarettes. Not conversant in Panoan, the Mayoruna language, I finally pointed to the scars and indicated that I wanted to know what had caused them. Several youths smiled at me and then ran into the forest. After twenty or thirty minutes, they returned bearing a leafy branch on which sat a large, handsome, green frog.

I thought it very kind of the boys to show me this wonderful frog, but I had no idea that it was connected to my question about the burn marks. I wondered if the boys thought I was hungry and were offering the frog to me for my supper. They allowed me to admire it for some minutes as it sat calmly on the branch and then on the shoulder and arm of one young man. It was a vivid green, with striking yellow mottling on the underside of its limbs and body, and it moved with an exaggeratedly slow gait, similar to that of the African chameleon. But then the boys took the frog and began to prepare it for some kind of procedure. I finally realized that the frog did have something to do with the burns after all.

Without touching the animal, the boys looped slender cords made of vines around all four of its limbs. They then drove small stakes into the ground and stretched the frog out, firmly attaching the cords to the stakes. At that point, several of them picked up wooden splinters and began to harass the frog, poking it particularly around the eyes and nostrils. In response, the terrified frog began to exude a clear, glossy secretion from its skin that began to settle in a cloudy, mucuslike film around its feet. I had no doubt that this was some kind of potent substance that the frog used for defense. Did contact with it cause burns? Using a splinter, the boys

A Matses hunter in Peru, an expert with bow and arrow, displays a common piping guan he has shot.
Jeff Rotman

Katharine Milton



scraped the secretion off the head, back, sides, and limbs of the frog.

After the frog had been poked and scraped for some minutes, its ability to produce the secretion evidently was exhausted. At that point, the captors carefully removed the cords from the frog's limbs and permitted it to walk away. The frog was not physically damaged, only frightened. One boy who briefly touched the frog while removing the cords ran to the nearby river to wash his hands.

The secretion had been collected on a clean, flat piece of wood, which was placed near a fire to dry. The wood with the dried secretion—which looked like shiny glue—was then wrapped in cloth and stored in a secure, dry area in the thatch of a nearby house. On four occasions I observed how the frog's secretion was used in a type of hunting magic.

Traditionally, the Mayoruna live by horticulture (sweet manioc, plantain), hunting (tapir, peccary, woolly monkey, spider monkey), and some supplementary fishing. The men's skills with bow and arrow are impressive: "I pity the animal that crosses the path of a Mayoruna," remarked a visitor who had done considerable hunting with them. Yet hunting game in the forests of the Amazon Basin is always an unpredictable venture, a hunter never knowing whether on any given day he will have good luck, moderate luck, or no luck at all. Anthropologists have long noted that important activities with uncertain outcomes are the most likely to be surrounded with magical practices.

Detailed cave paintings, animal figurines, and stylized caches of animal bones found in Europe suggest that more than 30,000 years ago, human hunters were carrying out a wide variety of magical practices, possibly to improve hunting success. Ethnographic accounts of many past as well as present-day hunter-gatherer groups throughout the world describe a rich array of magical practices involving smoke, blood, bark, leaves, roots, and other substances, which the hunters believe improve their hunting prowess and luck, increase the numbers of prey, or propitiate animal spirits.

The Mayoruna use the frog secretion as a drug and regard its effects as a potent form of hunting magic. On two occasions when I observed the procedure, the drug was taken on a day of heavy rain—perhaps a bad day to hunt but a good day to practice hunting magic in preparation for more opportune conditions. I never saw a hunter take the drug by himself: two, three, or more men took it together.

To get the frog secretion into the body, the hunters heat a vine twig on a burning log until the twig is white hot. One man then takes the twig and applies it to the arm or chest of a person wishing to take the drug. The white-hot twig is allowed to rest on the surface of the skin for less than a second, then removed and reheated; each individual ultimately receives three to six burns, placed in a neat row, one under the other. At this point, the frog secretion is taken from its storage site and unwrapped.

When disturbed, a tree frog of the species Phyllomedusa bicolor, *far left, secretes a noxious substance, presumably a defense against predators. Amazonian Indians deliberately harass a frog, left, and collect the secretions on a stick for use as a ritual drug in hunting. (They will then let the frog go.) Small scars, below, show where the secretions have been introduced through the skin.*

Jeff Rotman

One hunter mixes his saliva with it, stirring it with a splinter to make a whitish, soft paste. The individual receiving the drug then uses his fingernail to carefully scrape away the small burned patches of skin, leaving open wounds. A small mound of the paste is then applied to each open burn.

Before receiving the burns, participants drink an impressive amount of manioc, banana, or other gruel. The first time I witnessed this, I didn't know why they did it, but I soon found out. The drug apparently enters the bloodstream through the open wounds very rapidly; within minutes it induces heavy, repeated vomiting. The Indians told me, through an interpreter, that the gruel lessens the pain. Another visible result is swelling of the lips and face; other rapid effects are headache and a burning sensation in the anal mucosa.

After vomiting several times, each participant sits quietly, often holding his head in his hands. Later he gets into his hammock and falls into a "sleep," during which he may babble and make other sounds. The sleep was described to me as exciting, rather than restful. Men say they think of "nothing" while in this sleep; that it is very similar to being very drunk. If they take the secretion about eight in the morning, they are recovering from its effects by five or six in the evening of the same day, although they may still lie about in their hammocks and act somewhat groggy. I was told, however, that if someone who is under the influence of the drug is thrown in the river or forced to bathe, he will rapidly shake off his somnolence.

I asked various Mayoruna why they took the drug since it appeared to be so unpleasant. The men replied that taking the frog secretion "made them hunt better." Taking it was said "to get rid of bad luck, help you to keep good luck, and help your arrows find the game animals." Men also stated that taking the secretion made them physically much more powerful—their senses keener, their stamina greater, their aim with the arrow more precise.

I was told that Mayoruna boys are first given the frog secretion when they are about seven or eight years of age "so that they will become accustomed to taking it." Women occasionally take the frog secretion so that "they will work harder." I estimated that most or all adult male hunters in Lobo take the frog secretion at least once a month.

The Mayoruna Indians in Lobo have another type of painful hunting magic. Men seek out large "fire" caterpillars, whose three-inch bodies are covered with long, white, stinging hairs. My one contact with one of these caterpillars produced such immediate, excruciating pain that for months afterward I flinched at the mere thought of white, fuzzy objects. As caterpillars are soft-bodied, small organisms, they apparently require a very rapid-acting chemical defense against potential predators that would crush or ingest them.

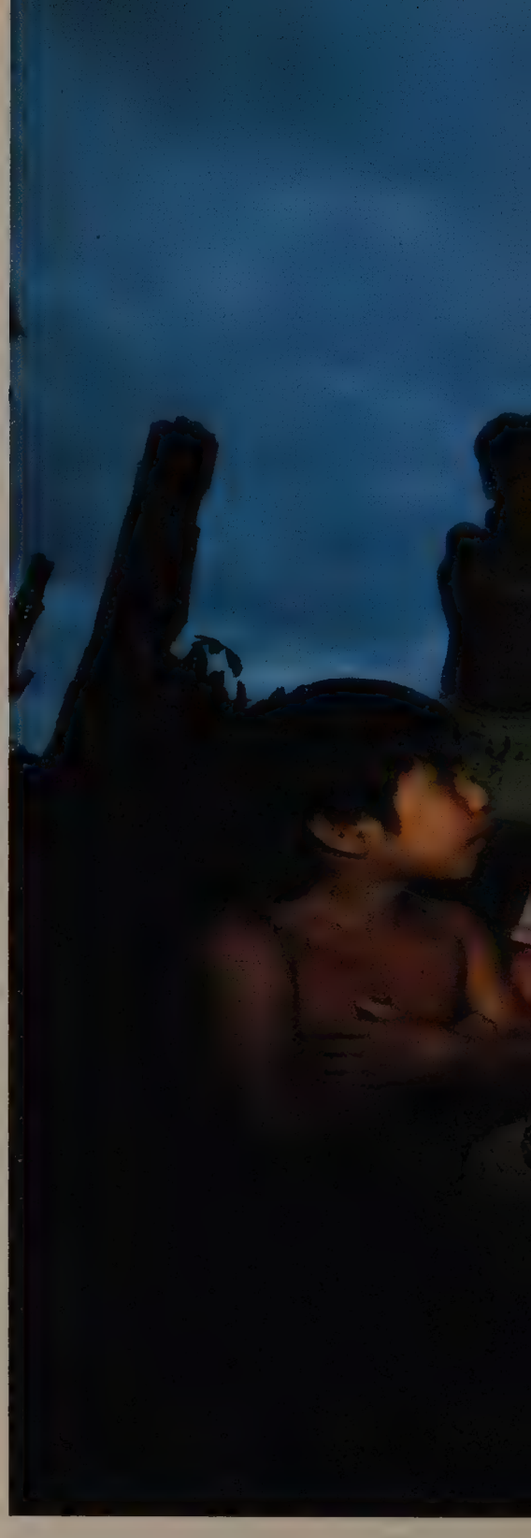
Some Mayoruna keep these white caterpillars on banana plants in their gardens so they will be readily available. To use them for hunting magic, they pick up the caterpillar on a twig and rub it on the bare upper arm. This practice, which is supposed to make a man a better hunter, leaves additional areas of scar tissue on the Mayoruna men and boys who take the frog secretion.

The Mayoruna I visited live in western Brazil, near the border with Peru. Steven

Jeff Rotman

The articles of manufactured clothing worn by young Matses, right, indicate their group's outside contacts. A Mayoruna boy, below, holding his family's catch from the river, and a Mayoruna teenager with his pet fawn, below right, belong to a much more isolated group.

Katharine Milton



Romanoff, an American anthropologist, has spent some fifteen months living with the Mayoruna of Peru, where they are referred to as Matses. His description of how the frog secretion is used for hunting magic matches what I saw almost completely, but he also mentions that the drug is sometimes administered to individuals (men, women, or children) who are lazy or are having problems or even as a punishment. Among the Matses, a dab of the paste may even be placed on the nose of a favored hunting dog to improve its hunting abilities.

Romanoff also observed a number of other energy-inducing rituals among the Matses. In these, an older man, respected for his knowledge or energy, blows tobacco smoke or uses stinging nettles or other painful materials to magically imbue younger individuals, usually men, with energy, strength, or knowledge.

While working with the Amahuaca Indians in a Peruvian headwater area of the Rio Inuya near the Brazilian border, anthropologist Robert Carneiro of the American Museum of Natural History also observed similar hunting magic. The Amahuaca, like the Mayoruna, are Panoan-speakers, and the two groups may be closely related. The Amahuaca men take a frog secretion (almost certainly from the same species of frog used by the Mayoruna) and place it in burns using the same technique. Carneiro, however, reports that in their case the effects last for some three days rather than a single day, and that Amahuaca men claim to experience vivid hallucinations while under the effects of the drug.

Amahuaca men also deliberately seek out wasps' nests and let numerous wasps sting them, believing that they will emerge from this ordeal better hunters. Youths may have strips of highly caustic tree bark tied around their wrists or forearms to insure that when they are hunting "no animal will escape."

Some years ago, Delvair Montagner Melatti, a Brazilian anthropologist, began to work with another Panoan-speaking group in Brazil, the Marubo, who live to the south of the Mayoruna and are one of their traditional enemies. The Marubo used the frog secretion extensively during her earlier visits, giving it to children as young as three years of age. Children typically did not like to take the secretion, which is unpleasant for anyone and which, in a small child, can produce very powerful effects. According to Montagner, taking the frog secretion appeared to be a daily or even twice daily ritual; however, the Marubo bathed very shortly after the secretion was administered. In some manner, the shock of the cold water and action of the bath curtailed much of the effect of the secretion, so the Marubo did not spend the rest of the day lying in a hammock but rather were able to hunt, work, or carry out other activities with vigor.

The Marubo stated that they used the secretion for two principal reasons—to rid the body of harmful impurities, including such things as bad luck, and to imbue the body with power, energy, and good luck. Children were given the secretion not only for these reasons but also as a punishment to correct improper behavior. In the past, the area of the body on which the burns were placed was apparently related to the type of effect desired. To cure laziness, for example, burns would be placed on the back of the neck, while to rid oneself of weakness and become powerful and quick, burns were placed on the stomach or upper arms. To improve hunting success, burns were placed on the chest and upper arms. To kill people in warfare, they were placed near the sternum. Painful, stinging herbs were also rubbed on the skin to augment the effects of the frog secretion. In her later visits, Montagner noted far fewer scars on the bodies of the Marubo and concluded that the practice was gradually dying out owing to the influence of missionaries and other outside forces.

The Mayoruna and others obtain the secretion from *Phyllomedusa bicolor,* a large tree frog that lives high in trees near rivers

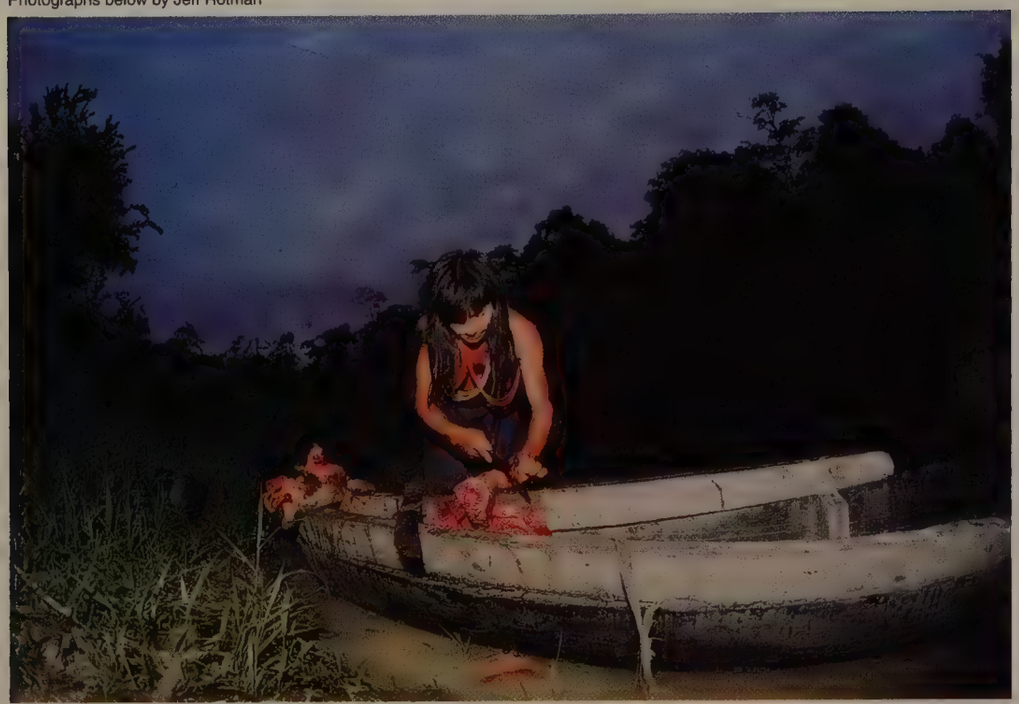
Katharine Milton

and streams. Curious about the chemical composition of the frog secretion, I obtained a dried sample and brought it back to the United States for analysis. I sent it to the laboratory of John Daly, a chemist at the National Institutes of Health, who along with his associate Charles Myers, a herpetologist at the American Museum of Natural History, is well known for studies of the chemical compounds in secretions of the so-called poison dart frogs.

Poison dart frogs of the genus *Phyllobates* produce among the most potent of all naturally occurring, nonprotein toxins—the batrachotoxin alkaloids. Some Indian groups smear the secretions from these frogs on blowgun darts in order to kill game. The poison leads rapidly to car-

A Matses woman, below, cuts up a tapir, a favored game animal. Bottom: A pot of tapir meat cooks over the fire. Opposite page: A Mayoruna mother wears straw whiskers to evoke the image of a jaguar. This adornment has now fallen out of use, but facial tattoos are still in fashion.

Photographs below by Jeff Rotman



diac failure in wounded game, but the meat of such animals is safe for humans to consume.

The secretion from the hunting magic frog, *Phyllomedusa bicolor,* is very different from those of poison dart frogs. Daly and his colleagues were able to isolate a previously unknown peptide, which they named adenoregulin. Earlier work by Vittorio Erspamer had shown that the skin of the frog contained a variety of vasoactive and opioid peptides. All these peptides presumably interact to produce the variety of symptoms and sensations noted in individuals who take the frog secretion. When some of the frog secretion was administered to mice at the National Institutes of Health, the mice fell into a drowsy trance. When the mice were stimulated, however, the effects of the trance could be rapidly dissipated—the same pattern of behavior noted in the Marubo, who bathe in the river after taking the secretion and then are able to carry out their daily activities with increased enthusiasm.

No one knows how tropical forest-dwelling people first acquired knowledge about the plant and animal compounds they use as medicines, stimulants, and magic. Most such discoveries were probably the result of some chance observation of the effect of contact with, or ingestion of, some leaf, bark, insect, or animal. The observer may have noted this effect on himself or on another person or animal. A series of trial-and-error experiments may then have helped determine how best to administer and use the chemical substances involved. To the best of my knowledge, the Mayoruna, and related Panoan-speaking groups among whom the procedure has been observed, are the only Amazonian Indians who introduce a drug into their bloodstream through a deliberate break in the skin. Elsewhere, such chemical substances are generally inhaled or swallowed.

Why many hunting magic procedures are painful or unpleasant is another mystery. Perhaps, as practitioners claim, the experience leaves them feeling energized and refreshed. The pain or stimulation brought on by frog secretions, wasp stings, stinging caterpillars, and caustic bark conceivably causes the release of brain peptide endorphins that ultimately lead to enhanced alertness, physical strength, and endurance.

Or more simply, hunters may believe that by subjecting themselves to some form of ordeal or discipline they are earning favor or investing themselves with extra power derived from animal spirits, deities, or ancestors. This added confidence and determination could enhance their hunting success. The limits of the human mind's influence over physical reality, at least over the body and health, are far from settled. Whether through a prayer, a fetish, or a frog, people throughout the world find ways to harness this resource. □

Photographs by Mike Severns

A male common house gecko feeds on a moth. Large eyes help this nocturnal insectivore in its search for food.

Gecko Power Play in the Pacific

Ever since they hitched a ride to Hawaii, competition between these little lizards has been driving them up the wall

by Kenneth Petren and Ted J. Case

After sunset on a South Pacific island, gentle trade winds sway the pandanus trees on the grounds of a local school. As day gives way to night, clouds of insects form around lights in the empty schoolyard. This is our cue to get down to work: collecting geckos, little lizards best known for the pads on their toes that enable them to perform Spiderman-like feats of climbing on almost any surface. Armed with powerful headlamps and long brooms, and with plastic bags dangling from our necks, we sprint to the first light. Holding our brooms aloft, we poke around the light, brushing geckos from the wall with frenzied actions. Then we move rapidly along the side of the building, sweeping under the eaves and pouncing on any lizards trying to escape through the grass. Once we have collected a few dozen of the finger-sized geckos, we catch our breath and decide to call it a night.

During the course of four years, we spent many nights, together with Douglas Bolger (formerly at the University of California, San Diego, and now at Dartmouth), in pursuit of common house geckos on Viti Levu, an island in the Fiji archipelago. Our goal was to monitor their numbers and study their interactions with other gecko species found in Fiji and on other South Pacific islands.

Many gecko species thrive in urban environments throughout the Pacific. All originated either in Southeast Asia or in the larger islands of the western Pacific, but they dispersed eastward by hitching rides with human colonists to the most remote islands. Geckos began their trans-Pacific trek thousands of years ago, stowed away in the cargo of Polynesian canoes. Some of the earliest stowaways belonged to asexual species, in which all individuals are females capable of laying viable eggs without male fertilization. Such species have an advantage over sexual species, as there is no need for both a male and female to start a population; a single individual or egg will do. Two asexual species that reached many of the Pacific islands by stowing away are the four-inch-long fox gecko (*Hemidactylus garnotti*) and the

Concrete aircraft hangars from World War II proved a good environment in which to study Hawaii's urban geckos. A fence kept predators out, and a strategic coating of blue Fluon (a suspension of Teflon particles the geckos can't cling to) kept the lizards in.

three-inch-long mourning gecko (*Lepidodactylus lugubris*). But since World War II, the increased volume of shipping in the Pacific has also enabled the common house gecko (*H. frenatus*), a sexual species, to colonize these islands.

All these geckos are nocturnal and insectivorous. Like tiny tigers stalking prey, they creep along, keeping their bodies pressed close to whatever they're walking on, and finish off the hunt with a final pounce and snap of the jaws. They may forage for insects on trees, plants, and buildings, requiring little more than a loose piece of bark or a wall mirror to hide behind during the day.

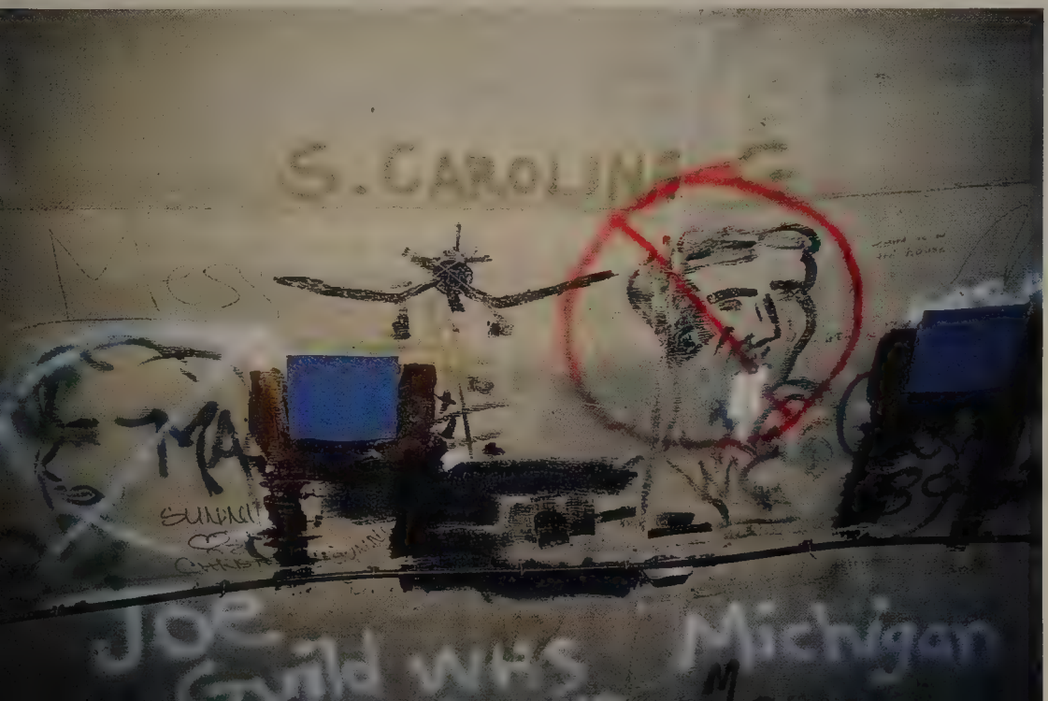
Flat walls, windows, and ceilings present no obstacle to these remarkable climbers. In fact, walls with overhanging eaves are a boon to the lizards: by impeding the insects' horizontal and vertical flight paths, the walls concentrate flying prey. These flat surfaces also generally make the insects more conspicuous than they are on cylindrical tree trunks. And with the advent of electric lights, the benefits of living near people became even more striking, for the lights attract a smorgasbord of flying fodder for the geckos.

But not all gecko species have fared equally well. Typically, once the common house geckos have established themselves in and around port towns, they quickly spread to other inhabited parts of an island and displace many of the earlier arrivals, including the fox and mourning geckos. The fox gecko, which is similar in size, shape, and habits to the common house gecko, is now very rare and simply can't be found in many of the places we see the other two species.

Our Fiji study demonstrated that as the common house gecko invaded, resident mourning geckos grew more slowly and their numbers decreased. Gecko skin is so thin and transparent that eggs can easily be counted and measured while still inside the female, enabling us to determine that the mourning geckos were producing fewer eggs as common house geckos took over. But what made the house gecko more successful than the mourning gecko? Was it simply its larger size?

To find out, and continue our investigations into the role of competition in determining the makeup and structure of a community of animals, we decided to expand our experiments with the geckos. Several aspects of the situation made us optimistic. The geckos are abundant and tolerant of handling by humans; the house gecko invasion tends to be rapid and have immediate, clear-cut effects; and given the geckos' penchant for urban environments, we could easily mimic a "natural" situation. All we needed were enclosures supplied with insects, hiding places, water, and egg-laying sites. With these ingredients, we thought we had the right mix to look for the actual mechanism of competition as it occurs on a relatively large scale, something that is not often observable during the lifetime of your average ecologist.

Hawaii was the logical place for this next phase of our research. The house gecko invasion is still in progress in some parts of the islands, and there are many small, abandoned buildings and bunkers left over from World War II. Our first task



The authors also set up four small enclosures, above, in one of the hangars. This enabled them to make detailed observations of all interactions between the common house and mourning geckos. Left: The space between a carpet-covered piece of thin Plexiglas (blue rectangle) and the graffiti-covered wall it is attached to provides a daytime hiding place for the lizards.

was to find a site with enough identical structures for us to set up experimental populations. Local residents sometimes hinted at the existence of such structures, but no one seemed to know just where they were. In our search for the appropriate site, we contacted more than twenty military bases and government agencies in Hawaii. Because we had few contacts at these installations, we had to start from scratch. The first phone calls went something like this:

"Hello, I'm looking for abandoned structures—maybe ten to twenty of them. Can you help me?"

"Well, I'm not sure. What do you want to use them for?"

"We want to do an ecological experiment with geckos."

"What? Did you say geckos?"

"Yes, geckos. Little lizards."

From the other end of the line came sounds of uncontrollable laughter, as colleagues were being told, followed by more laughter, and the reply, "I don't think so, but I heard that there were some old bunkers somewhere. I'm not sure exactly where, though." One military representative replied, "Sir, do you have any idea how the military works?"

Undeterred, we began to ascend the learning curve, amassing a huge network of phone contacts. We considered structures of all sizes and shapes, but eventually settled on the concrete aircraft hangars at Barbers Point Naval Air Station

Geckos are master climbers. Microscopic hairs on the white, oval toe pads of this common house gecko, left, enable it to cling to almost any surface. Two eggs are clearly visible in the mourning gecko below, photographed through glass. Under ideal conditions, she may produce a new clutch in as little as three weeks.

on Oahu. The hangars are solid concrete half-domes, sixty feet across, seventeen feet high, and forty feet deep, with one end completely open. They were built to protect small aircraft from the machine-gun strafing that devastated planes on the old Ewa airstrip during the attack on Pearl Harbor. The inner walls are often covered with graffiti, some of it nearly as old as the structures themselves, which gives the hangars a distinctly urban atmosphere.

The scrub forest around Barbers Point, like much of Hawaii, also shows abundant signs of human influence. The dominant tree is the kiawe, a mesquite introduced from North America. The leaf litter is densely populated with roaches (mostly nonnative) of all sizes, a food source that supports large numbers of common house geckos. The geckos, in turn, are fed upon by mongooses and feral cats, both introduced species that reach extremely high densities in these forests. Many of our initial experimental subjects fell prey to cats at night and mongooses during the day, until we constructed small fences to keep the predators away.

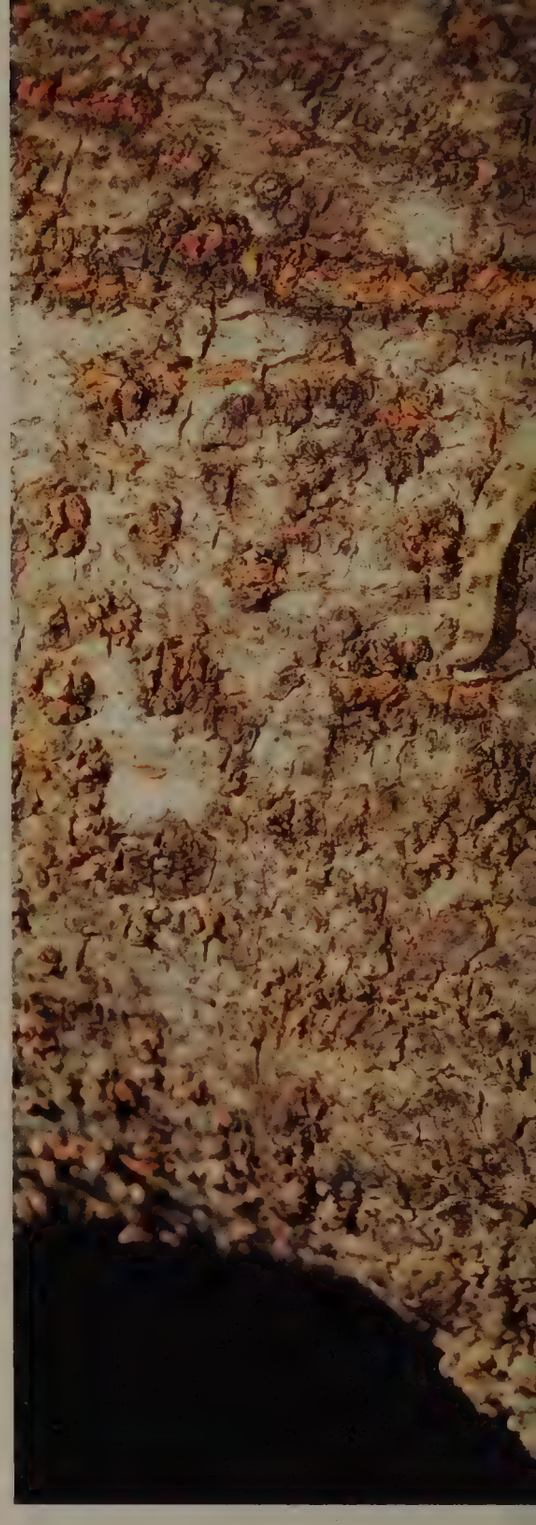
Three other introduced inhabitants pretty much round out the ecological picture at Barbers Point: termites, which eat kiawe and are eaten by geckos; scorpions; and centipedes. The centipedes are large and abundant. They eat the roaches but also prey on weak, lethargic geckos, consuming the entire body without leaving a trace. One of our less enviable maintenance duties was "centipede patrol," an attempt to reduce the numbers of centipedes trapped in our enclosures.

Our foray into urban ecology took on a distinctly military flavor when our area was periodically surrounded by armed troops decked out in full camouflage and face paint. During training exercises, they stalked and raided neighboring camps, using our hangars for cover. Particularly unsettling were the grenades, smoke bombs, and battle helicopters hovering below tree level, which would suddenly pop up and dart over the study site to deliver their armaments a stone's throw away.

Despite these distractions, we began making plans to convert eighteen hangars into separate, enclosed populations so that we could monitor the geckos closely and periodically conduct censuses. In the laboratory, we had confined geckos to their terrariums by smearing petroleum jelly along the tops of the tank walls. Gecko-proofing the huge hangars in this way would have called for hundreds of feet of the Vaseline barrier, spread by hand from fifty-five-gallon drums. Much to our relief, we learned of Fluon, a substance the entomological community uses to contain colonies of insects. A suspension of Teflon particles (the same Teflon—a product of NASA re-

A native of the Comoro Islands, near Madagascar, the gold dust gecko is a recent addition to Hawaii's already vast collection of introduced species. It is too early to tell if this new arrival will flourish and have an effect on native animals or other introduced geckos.

Mourning geckos, right, reproduce asexually. Different lineages of such clones can be recognized by the patterns on their backs.



search—that keeps your eggs from sticking to the pan), Fluon goes on like paint, and two coats will defeat even the most sticky-footed gecko.

With a satisfactory way to keep our gecko colonies intact, we began the painstaking task of renovation in the fall of 1991. We quickly learned that the skills of the urban ecologist may include painting, sweeping, hammering thousands of nails into concrete, and gaining an extensive knowledge of spray foam (to fill holes so the geckos could not escape the census). We used a variety of adhesives to secure our custom-designed gecko condominiums to the walls to provide daytime refuges for the geckos. Through a blend of creative electronics and laborious hauling of fifty-pound batteries for periodic recharging, we equipped half the hangars with a light, powered to turn on automatically at night.

There were plenty of common house geckos already inhabiting the hangars, but we decided to get all the geckos for our experiments—both mourning and common house varieties—from the same place, which meant gathering them at the few sites where mourning geckos are still abundant. (Mourning geckos continue to do well in many nonurban environments, especially in cooler, wetter, higher-elevation areas, where there may not be enough food for the larger common house geckos.) With our proven broom-and-bag technique, we collected hundreds of geckos and introduced them to the hangars. Many promptly escaped, which led to a frustrating period of design modification, more hammering and gluing, and restocking.

Eventually our efforts yielded a stable experimental system that was both gecko-proof and gecko-friendly. Now we could control all aspects of the experiment and take a completely new census of all populations (twenty geckos per hangar) every eight days. Some hangars had only one species, while others had equal numbers of both species. On census days, I moved from one end of an enclosure to the other, capturing, identifying, and measuring all geckos as they were caught fleeing their refuges. The design of the enclosures enabled daytime census taking, so a headlamp wasn't necessary, but a small broom proved indispensable for the roundup.

After a few weeks of settling in, we had results that agreed with our Fiji findings: mourning geckos became thinner and produced fewer eggs when common house geckos were around. This effect was seen, however, only in revetments with electric lights. Since insects concentrated near the lights, we theorized that the larger house geckos were monopolizing these insect-rich patches. The real excitement began when we placed a blind near the light and started to observe the geckos' interactions on the vertical wall near the light.

To our surprise, the all-female mourning geckos were very aggressive toward one another, something not seen in our earlier studies of captive individuals in terrariums. Long-drawn-out battles raged over positions near the light. Opponents made clicking and growling noises, arched their backs, turned side-to-side, and then—clamping their jaws down on each other's head or body—locked into a wrestling position. At this point, one gecko usually let go and retreated, although sometimes the fight continued, with one gecko suspending the other in midair and the dangling gecko avoiding the fall to the floor only by keeping its jaws tight on the other's head. Often both would fall to the ground—sixty body

lengths or more—and immediately begin the long climb back up to the light.

While aggressive interactions between mourning geckos were almost constant, the situation with the common house geckos was less clear. Males spent much of their time patrolling for other males and would drive them off instantly in battles similar to, but much swifter than, those of the asexual mourning gecko. In contrast, females, which are smaller than males but still larger than mourning geckos, simply foraged side-by-side at the light, feasting on their favorite foods—winged termites and moths. Males would essentially ignore females except when feeling amorous; then a brief tail-wagging, followed by copulation, would take place, often directly on the light in the middle of the feeding frenzy.

Our biggest surprise was discovering that the common house gecko was not aggressive toward the mourning gecko, even when ten to fifteen geckos of both species were crowded within three feet of the light. In fact, the most dominant mourning gecko would often attack and bite a larger common house gecko, which appeared unimpressed and seldom retaliated. Further, our censuses revealed that members of the two species commonly shared refuges during the day as well, so there appeared to be little or no direct aggression day or night. Why then does the mourning gecko fare so poorly in the company of its larger relative?

At least part of the answer was revealed in a small-scale experiment constructed solely for nighttime observation. We set up four enclosures, placing eight mourning geckos in each of the first two, and eight common house geckos in each of the remaining two. All enclosures had an electric light. After a couple of weeks, we removed the four least active mourning geckos and replaced them with four active common house geckos and watched to see what happened. The results depended on the social status of the individual mourning geckos: in each enclosure there was a dominant individual that never lost a fight with another mourning gecko and that usually sat right on the light, where insect foraging was best. These dominant

A common house gecko, below, hugs the wall as it stalks a moth. Right: The mourning gecko gets less to eat when its larger, faster relatives are around.

mourning geckos actually spent more time at the light in the presence of common house geckos, while the subordinate mourning geckos moved even farther from the light to forage in less productive areas. Foraging even a few inches from the light can make a huge difference, as insect numbers drop off dramatically with distance from the light. Since this experiment, we have learned that this subtle displacement is still evident months after the introduction of common house geckos.

We have also learned that even dominant mourning geckos are worse off in the presence of common house geckos. In spite of having access to the best seat at the insect smorgasbord, they get less to eat. This may be partly because mourning geckos spend so much time fighting with one another: time spent fighting is time not spent eating. The male common house geckos not only end their fights quickly, but they are also larger and faster than the mourning geckos and thus better at catching insects. Meanwhile, because female common house geckos forage peacefully side by side, they may be able to catch more insects. In this way, the different roles of males and females in the sexual species may give them an overall advantage over the asexual mourning gecko.

Although the aggregations of insects around lights appear to be the key feature giving the common house geckos a competitive edge, long hours of observation may ultimately lead us to conclude that there is no single dominating mechanism of competition, but many interacting mechanisms. And as the story continues to unfold, new questions come up. Can a subordinate mourning gecko, for example, eventually overcome its fear of house geckos and rise to replace a dominant individual that has died or moved on? We also hope to learn more about juveniles, which may have an especially strong incentive to stay clear of house geckos: under extreme circumstances, they themselves may become dinner for one of the large male common house geckos. We expect it will be a while before we have answered all the questions raised by these little lizards. In the meantime, we are perfecting our skills with hammer and glue. □

Broadcast Blues

I hear America singing

by Roger L. Welsch

There are some questions for which there are no answers, problems for which there are no solutions, science or not. Take that periodic, pandemic dreariness that seems to invade the human condition. We have a literary phrase for it—*mal de siècle*—but it remains generally unexplored and unexplained by science. Psychology is into its second century and yet the human mind, not to mention the cat's, is like a sealed book with uncut pages.

This morning I was still in my pajamas when I walked past our upstairs bathroom, where my daughter Antonia was getting ready for the day. "How's it going, Honey?" I asked. She didn't hear me because her radio was blaring the latest tune by Billie Bob Clintstone, " 'Despair' Ain't Quite the Word for the Misery I Feel":

> You done left me here, a cowboy
> broken-hearted,
> So's I done gone over to the Wal-Mart
> and carted
> Enough Ding-Dongs and Ho-Hos to
> ease my ruint ego;
> Cowgirls like you ought to be illegal...

I turned down the radio and greeted her again: "Good morning, Antonia. Nice day, huh?"

"Oh, I guess so, Dad. It's just that I'm feeling kind of down."

"Problems at school?"

"No, I don't know what it is. I just don't feel very spunky."

"Well, sorry, Hon. Hope things go better when the sun comes up."

I went downstairs and kissed Linda good morning. "Mind if I turn down your tape deck so I can watch the morning news?" She was listening to her current favorite, Rita Mae Hardtime, singing "You're a Rotten, Stinking Puke and I Don't Gotta Take It No More":

> You're ugly and you know it,
> You're a degenerate and you show it;
> You've betrayed me, lied, and ran,
> But I love you, my beer-guzzlin',
> womanizin', snooze-chewin' man...

"You look like you've been crying. Are you okay?"

"Yes, I'm just feeling a little blue this morning. I think maybe it's the bad weather. I just can't seem to shake it. Maybe I'll feel better once I get some coffee."

"Antonia's feeling a little down this morning too. Well, I'm going to run up to town for the mail. Be back in about a half hour."

I stepped out into a beautiful spring morning. The sun was shining and the birds singing. Down beyond the trees I could hear the sound of the river running strong and deep. I leaned up against my pickup truck and admired the morning's warmth and calm for a moment before I jumped in and started her up. Linda must have been driving the truck the day before because she had set the radio to her favorite country-western station, MZRY. Whining steel guitars. Even my amateur ear could hear that the guy who was singing needed adenoid work pretty seriously:

> I knowed that you was cheatin', but
> why with my best friend?
> Think I'll take my old .44 and put this
> all to an end;
> I'd throw myself off a bridge, end the
> worry and fritterin',
> But with my luck I'd get picked up by
> the EPA and throwed in jail for
> litterin'.

The dogs always howl like a fire siren when they hear songs like that, so I turned off the radio and drove into town about half speed, enjoying the day. The rattles of the loose frame and the whine of the bad steering pumps on my battered Ford seemed a major improvement over anything I could find on the radio. I was feeling pretty good by the time I got to the post office. "How's it going, Fred? Nice day, huh?" I said to the postmaster.

He turned down his radio, and I'm glad he did, because he was listening to yet another country-western station, DWNR. Darlene Dourndrear was sobbing something about

> We was beaten, starved, and flailed,
> Specially when Pop was jailed;
> Mom tried her best, but had to work us
> So hard, we didn't even get to go to the
> circus.

"I like Darlene," Fred said. "She sings about real things from her own life. Like me. Even though I have a great family, a good job, and live in a lovely town, I'm not feeling so good about life myself these days."

"Fred, I was reading in *Newsweek* last month that Darlene Dourndrear's real name is Margot DuPont, she attended Bryn Mawr, was a debutante, and inherited enough money to buy Poughkeepsie. Singing country music is only her hobby."

"Yeah, I heard that too, but the thing is, she sings about real things that are probably happening to other people. Like me."

"Right, Fred."

Yvonne Buchanan

"About half your mail today is from folks trying to raise money for charities, Rog. Here's the National Depression Hotline, and the Fund for the Generally Down on Their Luck, the Malaise Society for the Prevention of Cruelty to the Bummed Out, and…."

I tossed the flyers into Fred's wastebasket and drove home the long way, taking the gravel road down by the creek. As cheery as I was feeling, I couldn't help wondering what the heck was going on in the world to make everyone so troubled and beset—that mystery that science may never solve. I took the turn over toward Beecher's Pond so I could take a look at how the muskrats were coming along with their spring work.

I tried the radio again and with great good fortune found a public broadcast station buried between two high-watt country-western stations. Ah, Beethoven's Ninth, right at the point where the chorus sings Schiller's "Ode to Joy" (in German, of course, but roughly as follows):

> Joy, sweet balm of the gods, daughter of Elysium,
> Intoxicated with your fire, we enter your divine sanctuary—
> Your magic heals even the most angry divisions of our time.
> We are all brothers and sisters beneath your gentle wings…

I got into the music pretty good and pushed the pickup a little hard, but I backed off again when I got close to Beecher's Pond because there was a nice bunch of canvasback ducks sitting on the still water and I didn't want my whistling to scare them off. Finally, I couldn't contain my enthusiasm in the face of Beethoven and Schiller, so I cut loose with my locomotive-loud whistle and darn near hyperventilated myself.

The canvasbacks didn't budge—the Beethoven didn't bother them at all.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

On the Matter of Smallpox

Long before a safe vaccine became widely available, people took the risk of inoculating themselves with the smallpox virus

by Samuel M. Wilson

In April 1806, a package containing dried scabs and a vial of pus, taken from the open sores of a child in Mexico City, was sent by messenger to Manuel Antonio Cordero y Bustamante, governor of the Spanish provinces surrounding the missions of San Antonio, in what is now Texas. Governor Cordero's physicians lanced the skins of several hundred European-Americans and Indians living in the area and smeared the diluted pus and dissolved scabs into the wounds. As a consequence, these residents contracted cowpox, a disease closely related to smallpox. The antibodies they developed from the infection were to protect them from smallpox for the rest of their lives.

Distribution of the vaccine to this outpost of the Spanish Empire was due largely to the efforts of Francisco Xavier Balmis, a physician who sailed around the globe between 1803 and 1807 visiting settlements of the Spanish Empire. He was among the most courageous of souls not only because of the magnitude of his undertaking—more than 100,000 people in Latin America were vaccinated directly or indirectly through his efforts—but also because he struggled, along with many others, against the popularly held, intuitive sentiment that one did not preserve people's health by making them sick.

In a 1941 article in *The Journal of the History of Medicine,* S. F. Cook related how the Spanish king Carlos IV, terrified when his daughter contracted smallpox, had the rest of his family vaccinated after she recovered. Then, at his government's expense, he mounted the "philanthropic expedition of vaccination," putting Balmis in charge of getting the vaccine across the Atlantic to North and South America, and if possible, on to the Spanish Philippines. At the time, it was by far the largest vaccination program ever attempted. On the first leg of his journey, Balmis sailed from Spain to the Canary Islands and then to Puerto Rico.

Carrying the vaccine across the Atlantic was not easy. To vaccinate others, Balmis needed the "matter" of cowpox from the open sores of infected people—what we now know to be the active virus. That meant that he needed the pus and lymphatic fluid from people who were at just the right stage of the disease. Once infected, a victim showed no symptoms for more than a week. Aches, fever, and delirium set in about the ninth day, and at the beginning of the third week after exposure, blisters and pustules erupted.

So from the orphanages of Coruña, Spain, and surrounding areas, Balmis recruited twenty-two young boys who had never had either cowpox or smallpox. He then saw to it that they were infected with cowpox one by one as they crossed the ocean and traveled through Latin America, insuring that there would always be one person whose infection was at the right stage to pass on the disease. These twenty-two children were rewarded with the Crown's commitment to care for them until they were grown and to pay the costs of their schooling in the New World. Although little is known about how these children fared in the Americas or whether any of them ever returned to Spain, none of them died from their exposure to the disease, and they saved thousands.

Balmis's expedition was inspired by the work of the English physician Edward Jenner, who demonstrated that a patient could gain immunity against smallpox relatively safely by being infected with cowpox, a less dangerous disease that rarely proved fatal. In 1796 Jenner inoculated a child with pus taken from a cowpox sore on the hand of a milkmaid, who had caught it from an open sore on the udder of a cow. As Jenner records in a letter to a friend: "But now listen to the most delightful part of my story. The boy has since been inoculated for the Smallpox which as I ventured to predict produced no effect. I shall now pursue my Experiments with redoubled ardor."

Jenner was not the first to notice that contracting cowpox could save a person from getting a fatal version of smallpox later. It was part of local knowledge in rural Britain. Milkmaids routinely caught cowpox; afterward, they almost never contracted smallpox. But Jenner's experiments convinced the medical community that immunization was the best way of fighting smallpox and made cowpox the method of choice.

For centuries people had known that if you survived a bout with smallpox itself, you could almost never catch it again. They believed, often mistakenly, that a person who contracted smallpox through the skin, in the same way that milkmaids caught cowpox through the cuts or callouses on their hands, had a good chance of survival. They also thought that those who caught the disease from close contact with an infected person (evidently by inhaling the virus) were more likely to die or to have their bodies pitted and scarred by the pox.

Inoculation with smallpox itself, also called variolation, appears to have been common for centuries among rural populations throughout Europe, Asia, and

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Africa. Correspondence in the archives of the Royal Society of London shows that Englishmen had observed the practice in China before 1700. Several generations before Jenner's experiments, a furious debate had raged among physicians and town councils in Europe and America over whether inoculation with the "matter" of smallpox should be allowed. In the 1720s, in Boston and other New England towns, a war of pamphlets and posters was waged for and against the practice.

Inoculation was a chancy procedure. About 1.5 percent of those inoculated contracted severe cases and died of the disease, and sometimes recently inoculated people, who had not been kept in quarantine while they were contagious, spread the disease to others. But smallpox was such a ghastly disease that, to avoid it, people were willing to risk death for themselves and their children. In 1634, William Bradford provided an appalling description of what smallpox did to the Connecticut Indians:

They fell sick of ye small poxe, and dyed most miserably; for a sorer disease cannot befall them; they fear it more than ye plague; for usualy they that have this disease have them in abundance, and for wante of bedding and lining and other helps, they fall into a lamentable condition, as they lye on their hard matts, ye poxe breaking and mattering, and runing one into another, their skin cleaving (by reason thereof) to the matts they lye on; when they turn them, a whole side will flea of at once, (as it were,) and they will be all of a gore blood, most fearfull to behold; and then being very sore, what with could and other distempers, they dye like rotten sheep.

Later, Bradford notes that seeing the Indians' "woefull and sadd condition, and hearing their pitifull cries and lamantations, [the settlers] had compastion of them, and dayly fetched them wood and water, and made them fires, gott them victualls whilst they lived, and buried them when they dyed" (*Of Plimoth Plantation*).

The Puritan minister and prolific writer Cotton Mather (1663–1728) learned of smallpox inoculation from a man named Onisemus, who had been brought as a slave from Africa. Mather asked other people from Africa about the practice and found that it was commonly done there. Given the tremendous threat of smallpox epidemics in the new American colonies, he became a strong proponent of inoculation with smallpox. In his small book entitled *An Account of the Method and Success of Inoculating the Small-Pox,* printed

in London in 1722, he gave a step-by-step description of the procedure:

They make a Choice of as healthy a young Person as they can find, that has the Small-Pox of the best Sort upon him; on the Twelfth or Thirteenth Day of his Decumbiture, with a Needle they prick some of the larger Pustules, and press out the Matter coming from them into some convenient Vessel, which is to be stopt close, and kept warm, in the Bosom of the Person that carries it to the intended Patient. This Person ought rather to be some other, than he who visited the sick Chamber for it; lest he should carry the Infection in the common way, which might prove dangerous. The Patient is to have several Small Wounds made with a Needle, or Lancet, in two or more places of the Skin, (the best Places are the Muscles of the Arm) and immediately let there be dropt out of a Drop of the Matter in the Glass on each of the Places, and mix'd with the Blood that is issuing out. The Wound should be cover'd with some little Concave Vessel, and bound over, that the Matter may not be rubb'd off by the garments for a few Hours.

The dedication to Mather's book, written by J. Dummer, affirmed that the idea that inoculation with smallpox could prevent the disease was not at all new:

This Practice of ingrafting the Small-Pox has been used from Time immemorial among the Circassians, and for many Years past in the Levant, yet it is a new Thing in these Parts of Europe, and still more so in America: And as all new Discoveries, however rational in themselves, and beneficial to Mankind, are receiv'd at first with Opposition, none has met with greater than this in New-England.

In the late 1600s the practice of inoculation with smallpox had been described in Turkey and the eastern Mediterranean, and seems to have been widely used throughout Europe. Peasants called the rather dangerous practice "buying the smallpox," and most contemporary accounts noted (with either praise or contempt) that old women were the ones who knew how to inoculate people. A highly respected London physician of the early eighteenth century, for example, wrote derisively that "posterity will scarcely be brought to believe that a method practiced only by a few Ignorant Women, amongst an illiterate and unthinking People should...be received into the Royal Palace" (cited by R. P. Sterns, "Remarks upon the Introduction of Inoculation for Smallpox in England," *Bulletin of the History of Medicine,* 1950).

Even though these practices existed, no one at the time understood why the disease spread or why inoculation seemed to work

sometimes. Classical Greek physicians like Hippocrates based their treatments on the premise that diseases arose from imbalances in the four basic humors, a theory still current in the seventeenth century. The humors were blood, yellow bile, black bile, and mucus (the sanguine, choleric, melancholic, and phlegmatic humors, respectively). Disequilibrium among these humors was thought to cause the skin to erupt with the sores of smallpox, but just what caused the disequilibrium was unclear.

The celebrated Muslim physician Abu Bakr Muhammad ibn Zakariya Razi (better known as Rhazes) who lived from about A.D. 865 to 925, built upon the humoral theory of disease by suggesting that within each of us there is a case of smallpox (and many other maladies) waiting to boil out of our blood and erupt into open sores on the skin. His "innate seed theory" also involved the belief that changes in atmospheric conditions could trigger epidemics. Even into the nineteenth century this theory was probably the most widely accepted explanation for why people got sick (little wonder that Spanish conquistadors were so obsessed with the risks of staying in the "unhealthful airs" of the American tropics).

While these humoral and innate seed explanations were widely accepted, a remarkably modern theory was proposed as early as 1546 by an Italian from Verona, Girolamo Fracastoro (1478–1553). In his *De Contagione et Contagiosis Morbis et Eorum Curatione,* he argued that *seminaria*—in effect small seeds of disease—could be transmitted from person to person through a variety of means. Each disease (he addressed measles and smallpox specifically) had its own unique *seminaria*. Fracastoro also spent much of his career studying "the French disease"—syphilis.

After the Dutch businessman and amateur lens grinder Anton van Leeuwenhoek (1632–1723) refined the single-lens microscope in the seventeenth century, the existence of microscopic organisms was demonstrated, and Fracastoro's theory of *seminaria* was revived in a new form. About the same time, a theory attributing the spread of smallpox to animalcules (minuscule animals) was also widely discussed. The smallpox virus was so minute, however, that it was not detected with the early microscopes. Thus for a time such explanations remained in doubt. In some of his writings, for example, Cotton Mather called the agents of the disease

"animalculae" of uncertain character, but in others he called them "miasms" (miasmas, or vapors).

"The venomous Miasms of the Small Pox," Mather wrote,

entering into the Body, in the Way of Inspiration, are immediately taken into the Blood of the Lungs; and, I pray, how many Pulses pass, before the very Heart is pierc'd with them? And within how many more they are convey'd into all the Bowels?

In an elaborate discussion he compared the body to a fortress, and argued that if the miasms came in through the lungs, they were deadly, but if they had to fight their way through the "Out-Works of the Citadel," the person's skin and muscle, they could be defeated.

But where did the miasmas come from? In the early 1700s, no one knew. The English physician Thomas Sydenham (1642–1689)—whose opinions, so powerful in the inoculation debates in Boston in the 1720s, were well known to Mather—believed that "noxious miasms" issuing forth from the earth into the atmosphere were responsible for epidemics. Sydenham's 1666 treatise, *Methodus Curandi Febres,* was based on this "miasmic theory" and was the most influential reference available in its day.

The treatments that doctors used to treat smallpox, however, had little to do with the theories of how the patient got the disease: Rhazes believed that imperceptible atmospheric changes brought illness and advocated "heat therapy" to warn the body of an invisible threat and drive away the infectious humors. Fracastoro believed that *seminaria* had somehow entered the patient's body and went along with Rhazes in hoping that heat might drive them out again. Sydenham's theory did not contribute to the understanding of how people got smallpox, but rather to its clinical treatment. He argued that heat therapy with steam and blankets was the worst treatment since it exacerbated the sores and helped to spread the contagion.

From the idea that diseases were spread through microscopic seeds or animalcules, it was a small step to understanding that different diseases were brought about by very different animalcules. "The Pestilence can never breed the Small-Pox, nor the Small-Pox the Measles...any more than a Hen can a Duck, a Wolf a Sheep, or a thistle Figs," wrote physician Thomas Fuller in his 1772 *Pharmacopoeia Extemporainea.* Bacteriology and modern "germ theories" of disease were based on these concepts, and were further refined in the 1870s by pioneers like Robert Koch and Louis Pasteur.

Only in the twentieth century have scientists begun to learn how viruses invade the human organism and how the immune system can learn to identify and repel new threats. We now believe that vaccination with cowpox confers immunity to smallpox because the two are related members of a family of viruses, which also includes monkeypox, camelpox, buffalopox, and whitepox.

Although Jenner's method of vaccination became widespread, smallpox was extremely difficult to eradicate. Immunity cannot be passed on from one generation to another, so each new generation is vulnerable to smallpox epidemics. In a letter to Jenner, Thomas Jefferson wrote, "Yours is the comfortable reflection that mankind can never forget that you have lived. Future nations will know by history only that the loathsome smallpox has existed." He was right about the first part, but it took nearly two centuries to make the second part a reality (see *Smallpox and Its Eradication,* by Frank Fenner et al. [Geneva: World Health Organization, 1988]).

Just as Francisco Xavier Balmis needed a human chain of orphaned children to maintain an active cowpox infection during his Atlantic crossing, smallpox must spread from person to person in order to continue to exist naturally. By 1977, after a decade of intensive vaccination led by the World Health Organization, the virus was unable to find its next victim. Although a cure for smallpox had never been found, the disease was conquered.

Yet the virus is still maintained in laboratories for study. (In 1978, it escaped from a British laboratory, several people were infected, and one of them died.) Samples of the virus still sit in freezers in Moscow and at the Centers for Disease Control in Atlanta. Should we now keep it alive? The DNA sequences of several strains of the virus are known, and, if need be, the virus could be reconstructed using nucleotide sequences from other organisms. Thus, some argue that we should destroy the remaining samples. But if we keep them frozen, we may be able to learn more from them later. As one of the oldest and wisest of human adages says, keep your friends close and your enemies closer. The World Health Organization is expected to make the final decision in May 1995.

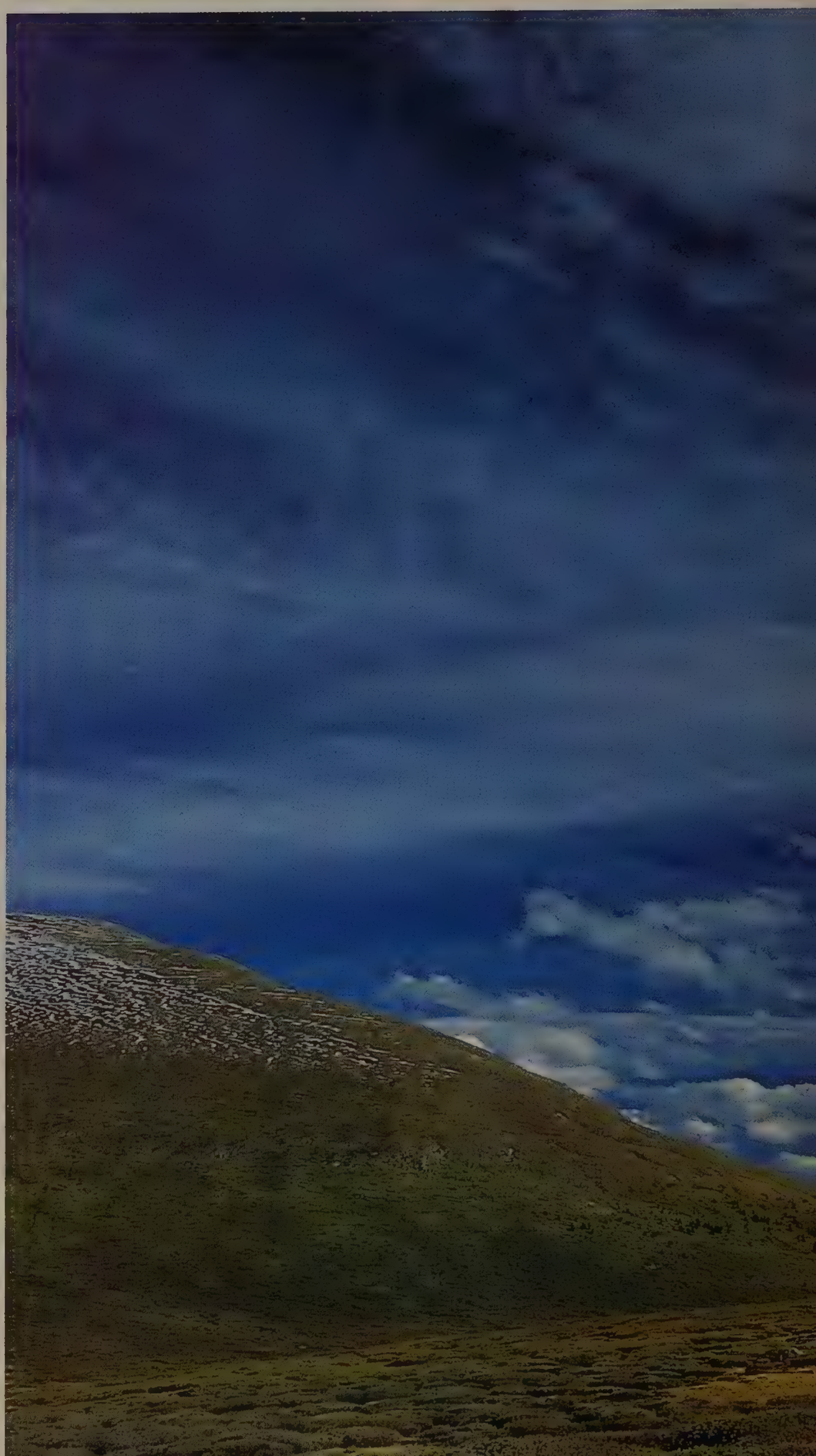
Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

Hoosier Ridge, Colorado

by Robert H. Mohlenbrock

The Continental Divide, the Rocky Mountain watershed that separates westward- from eastward-flowing rivers, generally runs north–south. Locally, however, it may run in more of an east–west direction. One such place is Hoosier Ridge, in central Colorado, a 11,600- to 13,200-foot-high crest whose slopes support tundra vegetation—stunted, cold-adapted species characteristic of high altitudes and high latitudes. Located in Pike and White River National Forests, it is most easily reached by taking Colorado Highway 9 to Hoosier Pass and hiking eastward.

To the west of Hoosier Pass lies the Mosquito Range, consisting of calcareous rock, or limestone. Hoosier Ridge, to the east, is essentially granitic. The most abundant vegetation lies on the moister, north-facing slopes of the ridge, where depressions are snow covered even in late spring or early summer. Here the dominant plants are tufted hair grass, with its threadlike leaves, and golden avens, a wildflower in the rose family. Other plentiful wildflowers are sky pilot, which is a handsome, blue-flowered member of the phlox family, and the densely tufted, pink-and-white-flowered whiproot clover, a species confined to granitic soil. In small, sheltered areas where the most snow and



Tundra vegetation cloaks Hoosier Ridge, on the Continental Divide. Right: A view northeast from Hoosier Pass.
Christine S. Beck

Don Kurz

Hoosier Ridge
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water accumulate, miniature, stunted trees of subalpine fir and Engelmann spruce grow alongside the equally diminutive gray willow.

South of the Continental Divide, on the warmer but drier south-facing slopes, the same golden avens and a grass known as kobresia prevail at the higher elevations, while tufted hair grass grows lower down, punctuated by shrubby, dwarf, gray willows and barren-ground willows. Scattered throughout the plant communities on both sides of Hoosier Ridge are areas of bare rock, bare soil, and permanent snowfields, where vegetation other than mosses and lichens cannot survive.

What makes Hoosier Ridge so significant botanically are some dozen rare alpine species that grow in isolation from their closest relatives. The most celebrated of these is Penland's alpine fen mustard, a three-inch-tall plant discovered on Hoosier Ridge in 1935 by botanist C. William Penland. Since that time, it has been found in a few other areas, all along a seventeen-mile stretch of the Mosquito Range crest. This rare plant grows in sphagnum-covered fens above 12,500 feet, habitats confined to small, flat ledges kept moist by surrounding, persistent snowfields. Such snowfields exist along the north slopes of this east–west portion of the Continental Divide; where the watershed runs north–south, the slopes are more exposed to the drying effects of the prevailing winds.

A tiny plant with minute, white flowers and shiny, heart-shaped leaves borne on slender stalks, Penland's alpine fen mustard is most closely related to Edwards' arctic mustard, found more than one thousand miles away in the Arctic Circle. Another species in the same genus grows in Asia. Because of its rarity, Penland's alpine fen mustard is being considered for the Federal Endangered Species list.

Other rarities include globe gilia, a sweet-smelling member of the phlox family, whose creamy white flowers form in a dense cluster at the top of a six-inch-tall stem. Although this species was first discovered in 1872, it has never been found anywhere in the world except on southern slopes along Hoosier Ridge and in the Mosquito Range.

Sea pink grows on rocky slopes in the Hoosier Ridge tundra at elevations above 12,000 feet. Its spherical clusters of pink flowers rise above a basal tuft of very narrow leaves. The only other places in the world where this species is found are in Canada's Northwest Territories and in Mongolia.

Weber's saussurea grows in the Beartooth Mountains of northeastern Wyoming and in the Belt Mountains of Montana, as well as in the tundra of Hoosier Ridge. It has purple flowers and is protected from the bitter conditions by woolly leaves and bracts. Its closest relative, another kind of saussurea, lives in Saskatchewan.

These and other rare wildflowers can be damaged or destroyed by trampling or other disturbance. Colorado has already acted to designate 925 acres of Hoosier Ridge as a State Natural Area. Since this zone falls within National Forest land, however, full government protection will not be assured unless the U. S. Forest Service designates this a Research Natural Area as well.

Sea pink grows in northwest Canada, in Mongolia, and on Hoosier Ridge.
Wendy Shattil and Bob Rozinski

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

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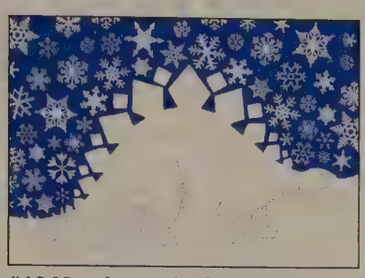

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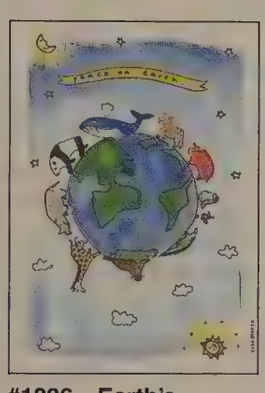

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A Change of Scenery

by Gail S. Cleere

In Plato's *Republic,* Socrates asks Glaucon, "Shall we make astronomy our next study? What do you say?" Glaucon responds, "Certainly, a working knowledge of the seasons, months, and years is beneficial to everyone, to commanders as well as to farmers and sailors." Socrates replies: "You make me smile, Glaucon. You are so afraid that the public will accuse you of recommending unprofitable studies."

While Socrates was not overly concerned about the utility of astronomy, today these "unprofitable studies" depend upon public support. Without public funds, the space probes to the planets would never have been launched and the Hubble Space Telescope would not be sending back its remarkable images of the distant stars and galaxies. There is, however, a very practical reason for spending tax dollars on astronomy. At the United States Naval Observatory in Washington, D.C., and the Royal Greenwich Observatory in England, the precise determination of the seasons, months, and years is the order of the day—not to mention a few other fundamentals such as the positions of the stars. This month, the Naval Observatory's *Almanac* tells us that the autumnal equinox will occur at 2:19 A.M., EDT, on September 23, and with that the season changes and fall begins.

You won't actually *see* anything at that moment. The nighttime constellations won't suddenly shift positions, and the leaves on the trees won't all suddenly fall down. But what will happen that morning (and this is something you can see) is that the sun will rise exactly in the east and set later that day due west. The equinoxes are the only two days of the year when this occurs. And if you happen to be on the equator, the sun will appear directly overhead at noon.

The equinoxes seem to have great appeal to the general public. An enduring legend—one that causes phones to ring incessantly at observatories across the country—is that at the precise moment of the equinox an egg can be made to stand on its end. It's not true, but the *St. Louis Post-Dispatch* reported one year that "hundreds of New Yorkers gathered at Ralph J. Bunche Park across from the United Nations at the moment of the spring equinox to sings songs, smoke controlled substances, chant slogans and balance eggs—all in the cause of world peace."

England's Stonehenge, rising majestically on the Salisbury Plain, draws mobs not only at the solstices but also at the equinoxes. Cullen Murphy, editor, essayist, and creator of the Prince Valiant cartoon series, described the regular contingent of neo-Druidic types that gather there for these occasions as a good-sized horde of "crank antiquarians, hardy perennials on the British scene, with their exotic opinions, their ample supplies of stationery, and the propinquity to a free press," as well as "trailer-based itinerants, of questionable cleanliness and with no visible means of support, whose purpose in life appears to be (in the words of press accounts) to alarm local authorities." Ancient sites in Egypt and South America also have monuments aligned to the equinox, and they, too, attract their astronomical enthusiasts.

Besides the phases of the moon, equinoxes and solstices are perhaps all that most people know about cyclic patterns of the sky. The changing sky, however, is repetitive and therefore easy to comprehend. Because the earth rotates on an axis that points almost directly toward Polaris, all the constellations move counterclockwise around the North Star, taking one full day to complete a circle. This means that when we are looking south at night, the constellations move from east to west by about 15° an hour. And, because the earth also revolves around the sun, the night side of our planet is facing a slightly different direction each night. This causes the scenery to change constantly, albeit slowly. The constellations rise about four minutes earlier each day, so new ones are always appearing on the horizon as the seasons advance, bringing us the diversity of the night sky throughout the year.

Earth's orbit around the sun also means that on the autumnal equinox, from our perspective, the sun moves to a place in the sky (in the constellation Virgo) that is 180° away from the fundamental reckoning point for all objects in the sky—the vernal equinox, which it reached six months earlier. Together, the equinoxes and the solstices are the four great events that shape the year.

Because our system of celestial coordinates is based on these points in the sky, knowing precisely when and where the equinoxes and solstices occur is vital. Without this information, we couldn't figure the exact positions of the stars, large telescopes could not be aimed, ships could not use celestial navigation, and spacecraft could not be launched with any hope of reaching their destination.

THE PLANETS IN SEPTEMBER

Mercury is visible very low in the western sky and sets within about forty-five minutes of sunset throughout September. A very thin crescent moon will be well to the left of Mercury and slightly higher in altitude on the 7th. On the 20th, Mercury will be just below and to the right of Spica in Virgo, and on the 21st, the two will appear side-by-side, with Mercury just off to the star's left (Mercury will appear twice as bright as Spica). You'll get a better glimpse of Mercury if you use a good pair of binoculars. On the 26th, it will arrive at greatest eastern elongation, or angular distance from the sun (26°).

Venus, too, is in the west at sundown, not far behind the planet Mercury, standing about 9° above the horizon at midmonth. It reaches its brightest magnitude (–4.6) on the 28th, shining with a brilliance unequaled by any other planet. On the evening of the 8th, look for a striking conjunction of Venus with a slender cres-

cent moon low in the west–southwest sky soon after sundown.

Mars rises after midnight not far from the twin stars Castor and Pollux in Gemini. Mars rides well above and to the left of the gibbous crescent moon during the predawn hours of the 1st. On the 30th, the orientation will be similar, but the separation between the moon and planet will be even greater.

Jupiter is nearing the western horizon at sunset, setting about two hours later. On the 9th, look for bright Jupiter off to the right of the waxing crescent moon. Venus, a much more brilliant object, will be just below them.

Saturn finally reaches opposition on the 1st, which means that it will rise when the sun goes down and stay with us all night long. Saturn is currently in the faint constellation Aquarius and will be easy to pick out as the night progresses. On the 17th and 18th, the nearly full moon will pass Saturn. On the 17th, the moon will be above and to the right of Saturn, and on the 18th it will stand above and to the left of the planet.

Uranus and **Neptune** are just left of the 3d-magnitude star Albaldah in Sagittarius, a relatively dim area in this constellation. On the 14th, watch for the first-quarter moon passing overhead.

Pluto, which is currently in the constellation Libra, sets before midnight. At +13.7 magnitude, about a thousand times fainter than the faintest naked-eye star, the tiny planet remains invisible, except to those with very large telescopes.

The **Moon** is new at 2:33 P.M., EDT, on the 5th; first-quarter moon is at 7:34 A.M., EDT, on the 12th. The full moon occurs at 4:00 P.M., EDT, on the 19th, and is called the harvest moon because it is the closest to the autumnal equinox. The moon reaches last quarter on the 27th at 8:23 P.M., EDT.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

The Market

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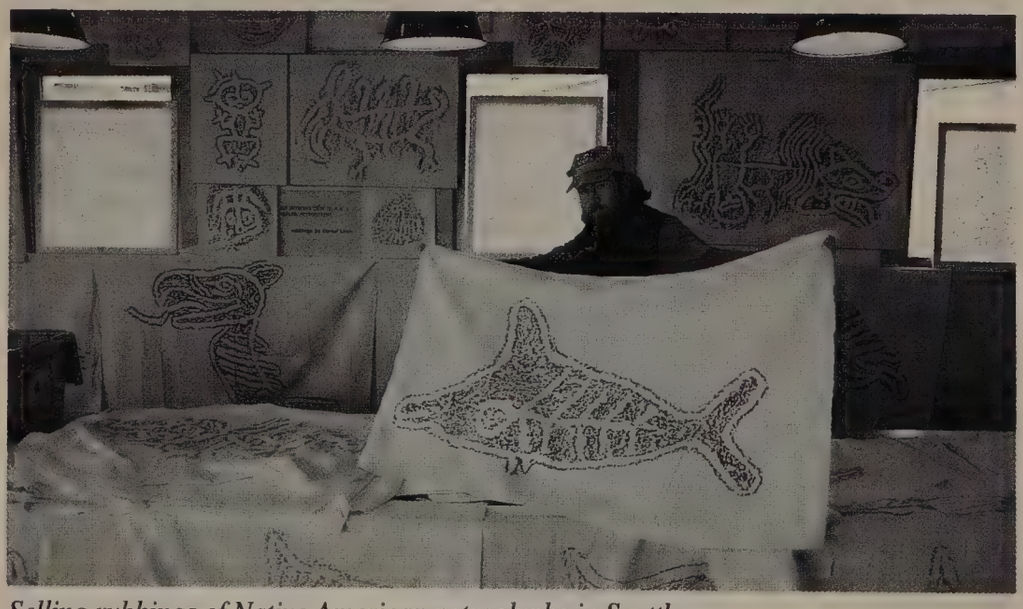
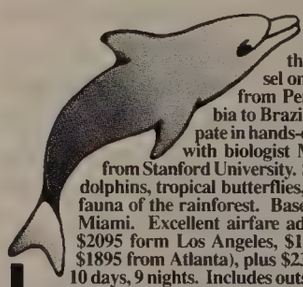


Selling rubbings of Native American petroglyphs in Seattle

Steve Meltzer



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Chaotic Cuddlers

What are downy, month-old emperor penguin chicks to do when the temperature drops to –30° F? To survive, they must maintain a body heat of 96° F, or 126° warmer than the air. Have they gone into a huddle to discuss the matter, or does misery want company? Neither, it turns out. Clumping in tightly packed groups of one hundred or more helps the birds stay warm, protects them against cold winds, and reduces an individual's rate of heat loss by 25 to 50 percent.

Emperors, the largest species of penguins, spend their entire lives at sea or on the antarctic sea ice, the world's coldest habitat. Yet the chick clusters, known as crèches, often generate sufficient heat to melt an oval depression in the ice. If a deeper hole forms near the center, some chicks may fall in or become trapped. Therefore, the crèche shifts its location often, pocking the ice with craters. Even later in life, as many as 6,000 emperors may crowd together during blizzards and severe winds—but adults huddle in orderly groups, while the chicks crowd together every which way.

Giant petrels may threaten young emperors that are left alone on the ice while their parents forage in the open ocean. Predators, however, tend not to bother chicks when they huddle in large crèches. During October and November, the antarctic summer, groups of chicks begin to congregate at the edge of the sea ice. Eventually, when a chunk breaks off to form a floe, the young penguins raft northward to warmer seas to begin their lives as adults.—*R. M.*

Photograph by Graham Robertson
AUSCAPE International

AT THE AMERICAN MUSEUM OF NATURAL HISTORY

EMPIRES BEYOND THE GREAT WALL

Opening Friday, September 16, in Gallery 77, a new exhibition, "Empires Beyond the Great Wall," traces 3,500 years of the history and culture of steppe empires, culminating in the reign of Genghis Khan. Among the exhibits are a gold funerary mask and more than 200 other works of art, including ornamental plates and vessels, porcelain, and gold saddle ornaments. Also featured are a full-sized re-creation of a recently excavated frescoed tomb, a yurt, and examples of Mongol women's traditional clothing. The exhibition will run through Sunday, November 27.

GENGHIS KHAN: HERO OR VILLAIN?

Nearly 800 years after Genghis Khan's death, opinions about his character and history vary. Was he a warrior-king who promoted cultural and commercial interchanges between East and West, a brilliant military commander, or a bloodthirsty barbarian? Morris Rossabi, professor of history at City University of New York, visiting professor at Columbia University, and author of *Kubilai Khan: His Life and Times* will talk about the life and career of Genghis Khan and his successors. The lecture, in conjunction with the exhibition "Empires Beyond the Great Wall," will be presented on Thursday, September 22, at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for ticket availability.

STORIES AND SONGS OF THE JEWISH NEW YEAR

On Tuesday, September 13, at 7:00 P.M. in the Main Auditorium, rabbi and folksinger Shlomo Carlebach and master storyteller Diane Wolkstein will celebrate, with story and song, the Jewish New Year, a ten-day period that concludes with Yom Kippur, the Day of Atonement. Call (212) 769-5606 for information.

AMERICAN MUSEUM: THE INSIDE STORY

The American Museum of Natural History celebrates its 125th anniversary this year. Two-hour walking tours, highlighting aspects of the Museum's vast natural history collection of more than 30 million speci-

Museum visitors in 1937 admire a turn-of-the-century reconstruction of a Brontosaurus *sporting a* Camarasaurus *skull (which was found in a Wyoming quarry near the giant skeleton). The dinosaur—now renamed* Apatosaurus*—will be reunited with its correct skull in the new fossil hall scheduled to open next spring.*
AMNH

n and artifacts, will take place on Friday, ptember 9, at 6:00 P.M., and Saturday, Sep-nb-r 10, at 4:00 P.M.

D- Saturday, September 17, at 11:00 A.M. d 1:00 and 3:00 P.M., Randall Schuh, cura- in the Department of Entomology, will d a special tour for the hearing impaired of department that contains the world's g- t insect collection. Free with admission, rs begin in the second-floor Rotunda near information desk. Call (212) 769-5562.

RTH CONTROL IN THE ANCIENT WORLD

According to Galen, the foremost physician classical antiquity, pomegranates, willow, d date palm were the most effective contra-otives. On Thursday, September 29, John ddle, a professor of history at North Car-na State University and author of *Contra-ption and Abortion from the Ancient World the Renaissance,* will speak on what has en recovered of these ancient botanical th control practices. The talk will be given 7:00 P.M. in the Kaufmann Theater. For re information, call (212) 769-5606.

ROYAL TOMBS OF SIPÁN: A LECTURE SERIES

From the richest pre-Columbian royal tomb ever discovered, archeologists have been able to determine the sophistication of the Moche people's metallurgy. Two Tuesday-evening lectures will be given in conjunction with the exhibition, "Royal Tombs of Sipán." On September 27, Craig Morris, curator of South American Archeology at the Museum, will place the Sipán exhibition in historical and scientific context. On October 4, Heather Lechtman, professor of archeology and ancient technology at M.I.T., will compare the metallurgy practiced in Andean South America with that of the Old World. The talks begin at 7:00 P.M. in the Kaufmann Theater, and tickets for both lectures are $20. For more information, call (212) 769-5310.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

Naturalist-author-photographer **Fred Bruemmer** (page 26) has studied the people and wildlife of the Arctic for thirty-seven years. A native of Latvia, he emigrated to Canada in 1950, at the age of twenty-one, and eventually settled in Montreal. Soon after, he began his forays to the north, traveling in an umiak, a skin boat of ancient design (*see* "Last of the Umiaks," *Natural History,* October 1992). His insatiable curiosity has led him to investigate ancient Eskimo ruins, the hunting habits of skuas, and the behavior of narwhals. But his greatest, most long-standing interest has been observing the lives of the seal clan. "Pinnipeds fascinate me," says Bruemmer, "and to study them, I have traveled extensively, from Lake Baikal in Siberia to Namibia, Antarctica, and Australia." *Natural History* has published the results of several of these studies, including those of walruses (November 1977), Hooker's sea lions (July 1983), Cape fur seals (November 1988), and hooded seals (July 1990). Among Bruemmer's many books on the natural history of the north, the most recent are *The Narwhal: Unicorn of the Arctic Sea* and *Arctic Memories: Living With the Inuit,* both published in 1993 by Key Porter Books, Toronto. For additional reading on seals, he recommends Judith King's *Seals of the World* (Ithaca: Cornell University Press, 1983).

For **David C. Houston** (page 34), the sight of a vulture probing the eye sockets or entrails of a carcass is as notable as that of an owl silently homing-in on a furtive rodent or an eagle swooping down on a rabbit. Specialists in locating and devouring the dead, vultures are adept at earning their living. Their feeding habits and ecological roles within various habitats have intrigued Houston since 1969, when he began a field study in the Serengeti. He has since studied Old World vultures in many parts of Africa and in India. For the past decade, his work on the forest vultures of Central and South America has enabled him to compare the dynamics of scavenging in New and Old World vultures. Houston, who received his doctorate in zoology from Oxford University in England, is now a senior lecturer in zoology and a member of the applied ornithology unit at Glasgow University in Scotland. His interest in the ecology of scavenging birds extends to part-time scavengers closer to home—ravens, crows, and hawks. Living in the west of Scotland, Houston often does fieldwork in the highlands, conveniently located right on his doorstep. For more information on vultures, readers can consult *Vulture Biology and Management,* edited by Sanford R. Wilbur and Jerome A. Jackson (Berkeley: University of California Press, 1983). Houston's chapter, "The Adaptations of Scavengers," in *Serengeti: Dynamics of an Ecosystem,* edited by R. E. Sinclair and M. Norton Griffiths (Chicago: University of Chicago Press, 1979) deals with African vultures.

Going Down the Drain

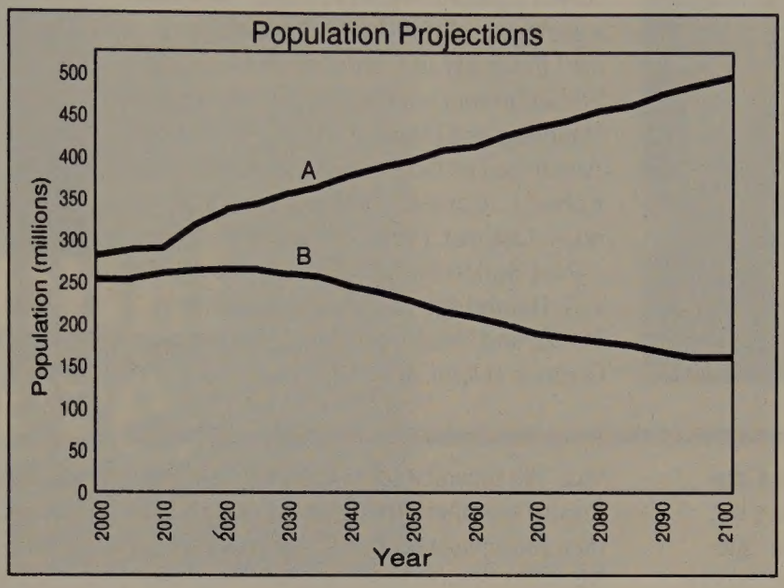
That headline may not be scholarly, and the tone is perhaps too flippant for a deadly serious matter. Still, it would be hard to find a more apt description of where our country is heading as a direct result of the relentless growth of our population.

The arguments for first halting, then reversing, U.S. population growth would seem so compelling as to raise the question "Why isn't it being done?".

Line A shows where our population is headed with current levels of fertility and immigration— to nearly 400 million by 2050, and to nearly a half billion by the end of the next century!

Such population growth would surely lead to disaster for future generations of Americans. It would have profound impacts upon the environment, on renewable resources like farmland, forests and water, and on our society itself.

A smaller population would help the nation deal with the social, environmental and resource problems that confront us, yet very few of our politicians and pundits even consider the idea.



On the assumption that they are held back by unwarranted fears, we will try to explain briefly by what relatively gentle adjustments we could turn U.S. population growth around.

Line B shows what could be achieved with the "two child family" and with immigration reduced to the levels that prevailed for much of this century.

If parents indeed "stop at two" it would lead to a total fertility rate (TFR) of about 1.5 children, because not all women have children, and some have only one. A national TFR of 1.5 would make possible a gradual turnaround in the population growth that drives our social and environmental problems.

We Need to Reduce Immigration

But the two child family alone will not enable the nation to reach a smaller population size. It would need to be accompanied by a substantial reduction in current levels of immigration.

In 1900 we were a nation of less than 76 million. Almost half of the population increase since then has been post-1900 immigrants and their descendants. The Census Bureau projects that our present population of some 260 million will increase by 2050 to 392 million (middle projection), or even to 522 million (high projection).

Of the population growth anticipated for the 21st century, nearly 90 percent will be post-2000 immigrants and their descendants. In other words, immigration is the driving force behind a disastrous surge of population growth.

The average annual level of recorded gross immigration from 1924 through the 1960s was 198,000. Immigration is now over a million per year. If we were willing to bring net immigration down to 200,000 a year, our demographic future would improve dramatically.

If we moved now to the "two child family" and concurrently brought immigration under control at an annual level of 200,000, it would lead in the next century to the population projection shown in the graph *(Line B)*.

By the middle of the next century parents could even be encouraged to have more children, for a total fertility rate of 1.9. That rate would allow our nation to maintain a constant population size of around 150 million.

If, at the same time, we change our lifestyles to reduce unnecessary consumption, and use energy and materials far more efficiently, such a population size should be sustainable for the very long term.

The Choice Is Ours

We need to choose the path leading to a sustainable U.S. population of around 150 million. To get there we would need the combination of the two child family and a moderate net immigration of 200,000 a year. What would be so difficult about that?

We need, above all, the courage to make now the decisions that would safeguard our demographic future. We urge Third World nations to bite the bullet and face up to their demographic problems. How about doing it ourselves?

NPG has recently published a paper titled, The Two Child Family, documenting the case made here. To become a member, and receive our papers on a regular basis, please send us your check today.

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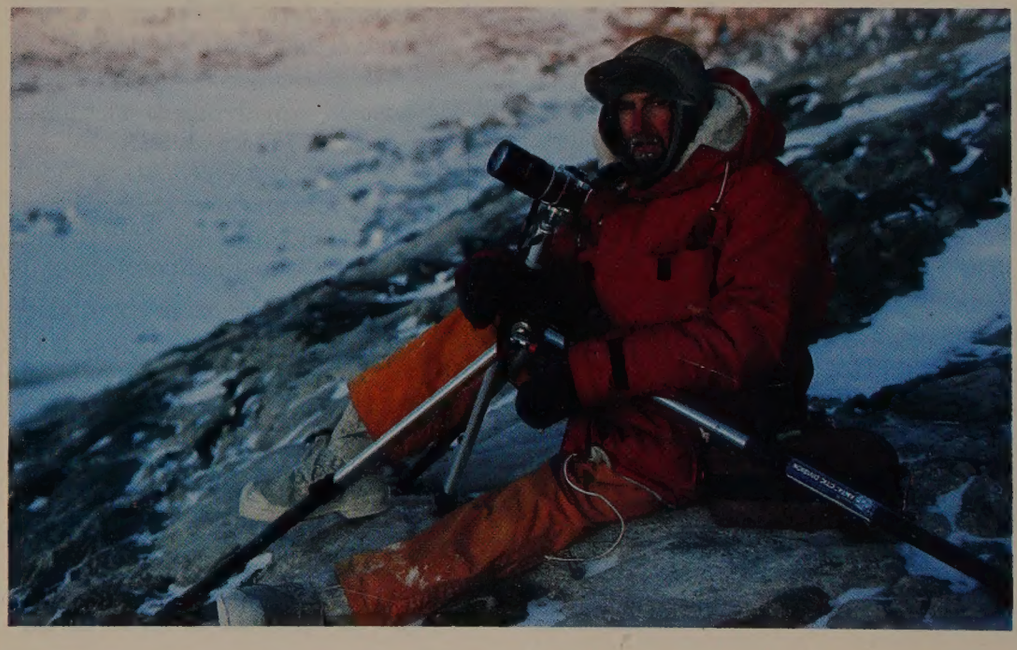
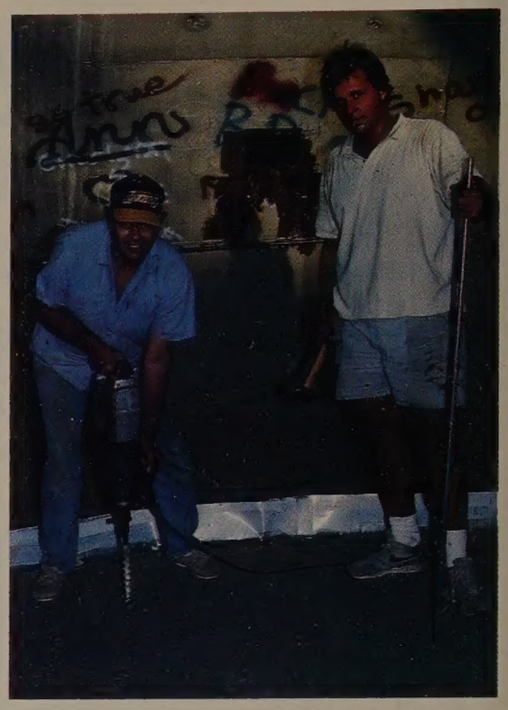
NH-994-HB23

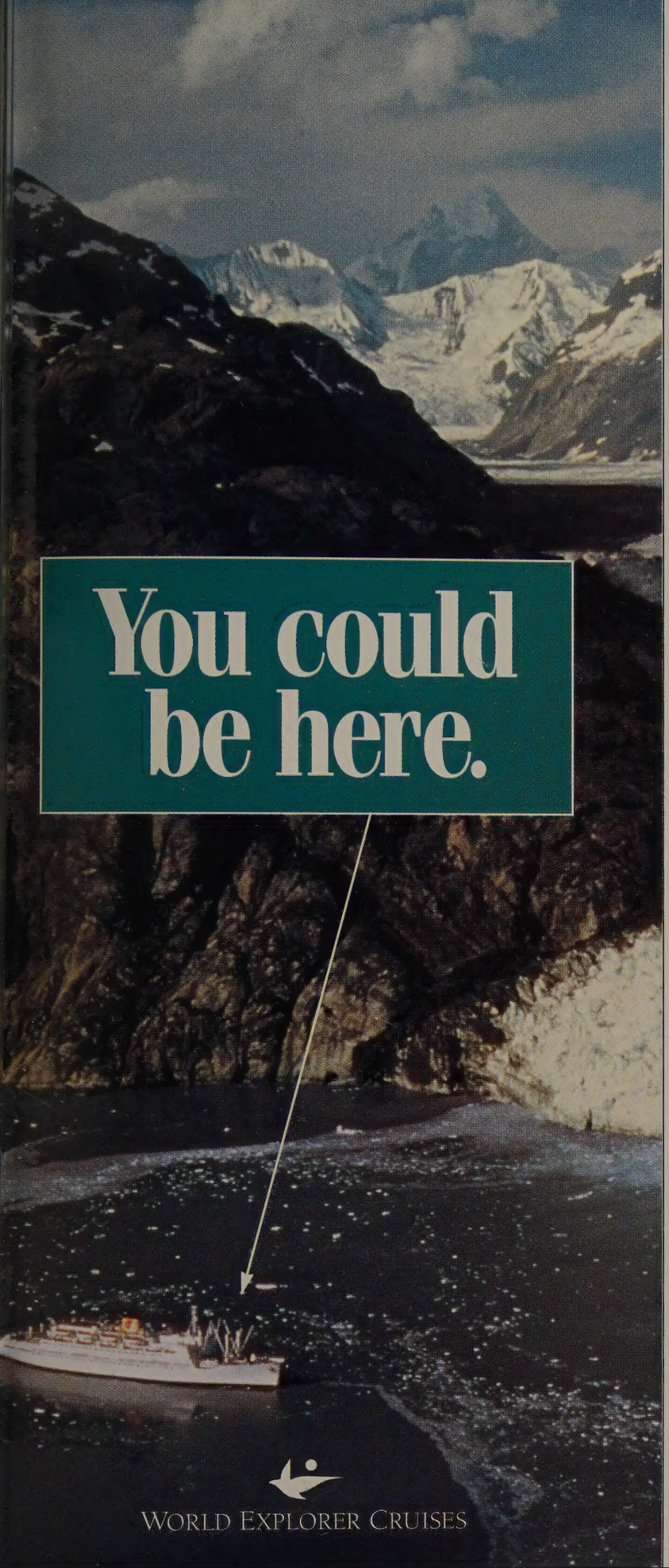
Although she originally went to Amazonia to study howler monkeys, **Katharine Milton** (page 44) has returned again and again to Brazil to record the lives of little-known groups of human inhabitants. She is especially concerned with how different indigenous peoples use the forest's resources, and with the nutritional components of their tropical plant foods and the significance of local food taboos. She continues to be interested in howler monkeys, conducting research in Panama on their interactions with a host-specific parasite, the howler monkey botfly. Among her side interests are neotropical parrots, in whose social nature, elaborate communication system, and high-quality plant food diet she perceives a parallel with primates. Milton is a professor of physical anthropology at the University of California at Berkeley. For additional reading she recommends "Hunting and Hunting Magic Among the Amahuaca of the Peruvian Montaña," by Robert L. Carneiro (*Ethnology,* vol. 9, no. 4, October 1970); "Frogs That Sweat —Not Bullets But a Poison for Darts," by J. S. Bainbridge (*Smithsonian,* January 1989); and "Making Magic," by Peter Gorman (*Omni,* July 1993).

Australian seabird ecologist **Graham Robertson** (page 78), says he considers the emperor penguin "the most remarkable animal I have experienced in twenty years as a wildlife biologist." He admires the bird's behavioral and physiological adaptations to the Antarctic, and "its wonderfully phlegmatic nature in the face of such extreme cold." Athletic as well as scholarly, Robertson represented Australia in the world championship pentathlon during the mid-1970s, then spent fourteen years studying red kangaroos and zone vegetation for the New South Wales National Parks and Wildlife Service. He recently completed his doctoral thesis on emperor penguin ecology based on a fourteen-month study at Australia's Mawson Station in Antarctica. To photograph the chick crèche at the Auster emperor penguin colony for this month's "Natural Moment," Robertson used a Nikon FM 2, with a 105mm f 2.5 lens and Kodachrome 64 film. "I had to be fast," he recalls, "because if I stayed too long, my presence would have caused the crowd of chicks to break apart and lose precious heat." When not in the field, the forty-five-year-old Robertson lives in Hobart, Australia, with his wife, two young daughters, and "a mob of horses."





Ken Petren (page 52) is a postdoctoral researcher in the Department of Biology at the University of California at San Diego. Coauthor **Ted J. Case** (left) is a professor in the same department. Case has studied ecological invasions in many parts of the world, including much of the South Pacific. Petren's initiation into the urban ecology of the introduced geckos came after he had spent three years studying birds in the pristine rain forests of southeast Peru. Both men believe that ecological research in urban areas may lead to insights not obtainable in wilder ecosystems and that, with human influence now penetrating all corners of the globe, such insights may prove especially valuable in any discussion of how to manage or repair "natural" systems. They hope, however, that all ecological work in the future will not by necessity be urban ecology. The two have traveled extensively between islands in the Sea of Cortés, investigating the evolution of body size in iguanine lizards. Petren, when not caught up at Gecko Central (their Hawaiian headquarters), pursues another passion: "Elvis biogeography," the study of the Elvis phenomenon in order to predict where and when the King will next be sighted. For more on some of the theory behind the authors' research, readers can take a look at *Community Ecology,* edited by Jared Diamond and Ted J. Case (New York: Harper and Row, 1985). Readers thinking of heading to Hawaii might want to get ahold of Sean McKeown's *Hawaiian Reptiles and Amphibians* (Honolulu: Oriental Publishing Company, 1979).



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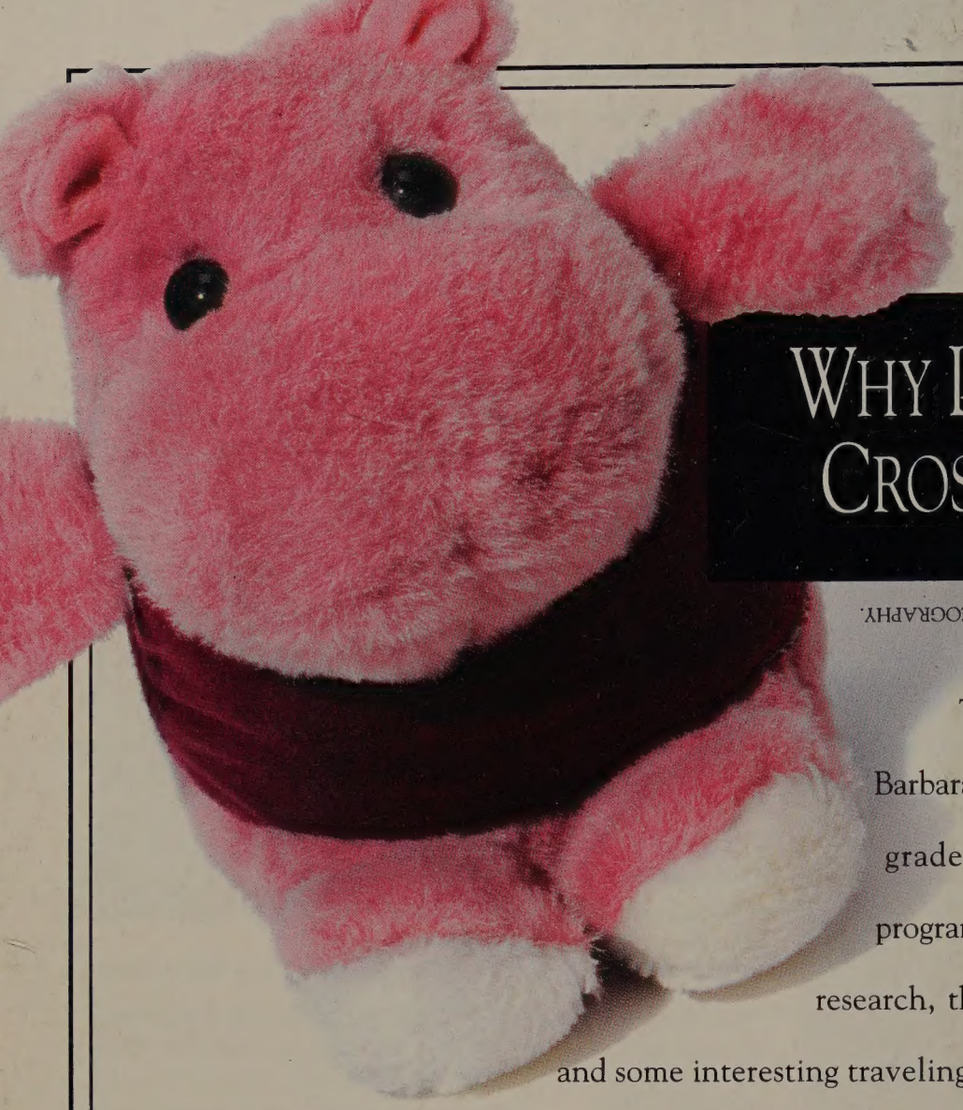

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